Lake Clark Sockeye Salmon Escapement and Population Monitoring, 2004 – 2007

Final Report for Study FIS 05-402

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ABSTRACT

Sockeye salmon originating from the Kvichak River watershed have historically dominated valuable subsistence, sport, and commercial fisheries in Bristol Bay, Alaska. Obtaining reliable estimates of spawning escapement over time from important subsistence stocks is the number one priority identified by the Subsistence Fisheries Resource Monitoring Program for Bristol Bay. This report describes findings from a salmon enumeration project conducted on the Newhalen River from 2004 – 2007. Specific objectives were to 1) estimate sockeye salmon escapement to Lake Clark and 2) determine the age and size composition of the Lake Clark escapement. Estimates of sockeye salmon escapement were made at river kilometer 36 on the Newhalen River using the same tower site and protocols that were used in previous studies. Sockeye salmon age and size were determined from otoliths collected from the Sixmile Lake subsistence fishery and from post-spawning fish at Lake Clark spawning areas. Total Lake Clark escapement, based on expanded counts averaged 592,059 fish and ranged from a low of 445,620 fish in 2005 to a high of 700,524 fish in 2006. The 2004 – 2007 mean escapement to Lake Clark was 274% higher than the recent (2000 – 2003) mean of 215,922, but 48% lower than the mean escapement of 1,135,464 during 1980 – 1984. During the study period, the Lake Clark escapement comprised, on average, 19% of the total Kvichak River escapement, which was similar to previous years. Run timing was also similar to previous years, although the 2006 run was approximately seven days later than average. Sampled fish were predominately ages 1.2 (46%) and 1.3 (38%), while ages 2.2 (11%), and 2.3 (5%) comprised the remainder.

INTRODUCTION

The world's largest, most valuable sockeye salmon fisheries occur in Bristol Bay, Alaska, and fish originating in the Kvichak River watershed (Figure 1) have historically dominated regional harvests (Forrester 1987, Dye et al. 2006, Fall et al. 2007, Ruggerone and Link 2006, Sands et al. 2008). During peak years in the 1960s and 1970s the Kvichak produced 23-42 million salmon per year and represented up to 80% of Bristol Bay sockeye salmon production (Ruggerone and Link 2006). Subsistence harvests of sockeye salmon in the Kvichak River watershed have historically been the largest within the Bristol Bay region and averaged 57,379 fish during 1987-2007 and 49,901 fish in 2007 (Sands et al. 2008). During 2001 – 2005 the average sport fish harvest of sockeye salmon in the watershed was 1,225 fish, making it one of the largest recreational fisheries in the region (Dye et al. 2006).

Since 1996, unpredicted declines in sockeye salmon returns to the Kvichak River and Lake Clark watersheds impacted regional commercial, subsistence, and sport fisheries. During 1996 – 2003 the average Kvichak River escapement declined 64% from 5.7 million fish during 1955 – 1995 (range = 0.2 to 24.3 million) to 2.1 million salmon (range = 0.7 to 6.2 million fish), and minimum escapement goals (2-6 million) were only met during two of eight years (Fair 2003, Morstad and Baker 2006, Sands et al. 2008). The Bristol Bay region was declared an economic disaster by the federal government due to poor salmon runs in 1997 and 1998 and by the State of Alaska due to poor salmon runs and low prices in 1997, 1998, 2001, and 2002. Annual subsistence harvests declined from a mean of 75,000 salmon during 1974 – 1995, to a mean of 47,496 salmon during 1997 – 2006 (Fall et al. 2007, Sands et al. 2008). Annual commercial harvests fell from a mean of 8.1 million during 1980 – 1995 to a mean of 1.4 million during 1996 – 2003 (Morstad and Baker 2006). Annual sport fish harvests also declined due to fishing closures and bag limit reductions (e.g., ADFG 2001 and 2002). Depressed runs to the Kvichak River have resulted in decreased spawning escapements (Figure 2) and failure to meet minimum escapement goals. Salmon production, measured by the number of adults produced by each spawning sockeye salmon has also declined, implying a slow recovery rate (Ruggerone and Link 2006).

The Kvichak River watershed contains two large lake systems, Lake Clark and Iliamna Lake, in which sockeye salmon spawn and rear (Figure 1). Lake Clark is a smaller watershed (9,583 km^2) than Iliamna Lake (11,137 km^2) and is also less productive due to the influence of active glaciers that make it colder and more turbid than Iliamna Lake (Demory et al. 1964, Mathisen and Poe 1969). Despite these characteristics, the Lake Clark watershed has at least 35 known spawning stocks (Woody et al. 2003, Young 2004, Young and Woody 2007a), and has comprised 7–30% (0.2-3.1 million) of the total Kvichak River escapement (Poe and Rogers 1984, Woody 2004). Similar to the decline observed in the Kvichak River escapement, the average Lake Clark escapement during 2000 – 2003 (0.2 million fish) declined by 81% compared to the average escapement during 1980 – 1984 (1.1 million fish; Poe and Rogers 1984, Woody 2004).

Several studies have previously monitored Lake Clark sockeye salmon escapement, and the longest time series of data consists primarily of aerial escapement estimates collected since 1955 (Demory et al. 1964, Anderson 1968, Parker and Blair 1987, Regnart 1998). Such data provide some indication of relative peak spawner abundance in select clear water tributaries, but typically underestimate actual escapement (Jones et al. 1998). A recent study by Young and Woody (2007a) indicates that up to 60% of Lake Clark sockeye salmon spawn in turbid waters and cannot be seen from the air. Past escapement indices conducted on the lower Newhalen River (river kilometer 1) from 1979 – 1999 and from 2001 – 2002 provide an indicator of run timing and strength into the Newhalen River relative to Kvichak River escapement, but data are less reliable in years of high water and high salmon escapement as both affect count accuracy (Poe and Mathisen 1981; Rogers and Poe 1984, Poe and Rogers 1984; Rogers 1999, Woody 2004.). Total escapement estimates derived from the index count range from 0.2–8.4 million sockeye salmon. Poe and Rogers (1984) used counting towers from 1980 – 1984 on the upper Newhalen River to provide a better estimate of total sockeye salmon escapement to Lake Clark, and reported Lake Clark escapements ranging from about 0.2 million to 3.1 million fish. Woody (2004) used the same site and protocols to monitor Lake Clark escapement from 2000 – 2003, and reported escapements ranging from about 0.17 million to 0.26 million fish, which represented an 81% decline compared to past studies.

STUDY AREA

The Newhalen River watershed is located in southwest Alaska within the Kvichak River watershed and includes the Newhalen River, Sixmile Lake, Tazimina River, and Lake Clark

(Figure 1). The Newhalen River is a clear-water tributary of Iliamna Lake with a length of 40 km and mean July flow between 16,000 and 26,000 cubic feet per second (cfs) and a maximum July flow of 36,000 cfs (USGS). A series of rapids and waterfalls located at river kilometer 11 affects salmon migration rates and during years of extremely high flows (> 28,000 cfs) creates a barrier to upstream migration (Poe and Rogers 1984). Sixmile Lake is a clear-water lake that is 10 km long and 1-2.5 km wide with an average depth of 5 m and a maximum depth of 35 m (NPS unpublished data). The Tazimina River is a clear-water tributary to Sixmile Lake with a length of about 87 km and a drainage area of approximately 829 km^2. Water from the upper portion of the watershed drains through two lakes; pours over a 30 m waterfall (river kilometer 15), flows through a canyon (~ 1.6 km) and finally winds 13.7 km through a low gradient (~3%) braided floodplain to its outlet in the upper Newhalen River. The Lake Clark watershed, located approximately 50 km upstream from Iliamna Lake and connected to it by Sixmile Lake and the Newhalen River to the southwest, includes Lake Clark and six primary tributaries. Lake Clark is the sixth largest lake within Alaska, the largest lake within Lake Clark National Park and Preserve, and is a semi-glacial oligotrophic lake that is 66 km long and 5-8 km wide with an average depth of 103 m, a maximum depth of 240 m, and a drainage area of 7,620 km^2 (Anderson 1969; Wilkens 2002). Of its six major tributaries, three are glacier fed, two are clear, and one is organically stained (Brabets 2002). Seasonal runoff from glacial tributaries is highest between June and September, and creates a turbidity gradient along the length of the lake from the turbid upstream end to the relatively clear downstream end (Brabets 2002; Wilkens 2002).

The Newhalen River watershed is a significant producer of sockeye salmon (0.2-3.1 million fish/year; Poe and Rogers 1984; Woody 2004) and contains at least 35 known spawning areas (Woody et al. 2003, Young and Woody 2007a). Primary spawning areas include the Tazimina River, Lake Clark outlet, shoreline beaches of Lake Clark and Little Lake Clark, Kijik Lake, Currant Creek, and the Tlikakila River (Regnart 1998, Young 2004, Young and Woody 2007a).

OBJECTIVES

1) Estimate sockeye salmon escapement to Lake Clark.
2) Determine age and size composition of the Lake Clark escapement.

METHODS

Lake Clark Sockeye Salmon Escapement

Lake Clark sockeye salmon escapement estimates were made at river kilometer 36 (Figure 3) on the Newhalen River, using standard counting tower protocols outlined in Anderson (2000) and Woody (2007). We used the same site and specific procedures outlined by Poe and Rogers (1984) and used by Woody (2004). Systematic, hourly, 10 minute counts were made from 6 m towers on both banks between late June and mid August 2004 – 2007. Night counts (0000 – 0400 hours) were made using rheostat controlled 12 volt lights powered by solar charged car batteries.

Counting was terminated for the season when daily escapement was less than one percent of the total escapement for at least three consecutive days (Anderson 2000).

Data analyses included calculations for hourly and daily escapement, missed counts, lag time from the Kvichak River, run time, and run duration. Ten minute counts were expanded by a factor of six to yield an estimate of hourly escapement past the counting towers. Daily escapement was the sum of the 24 hourly estimates. Values for missed counts were estimated using a regression estimate based on previous years of data, which was similar to the method used by Poe and Rogers (1984). Lag time between the Kvichak River and Newhalen River escapements was estimated by comparing the date when each escapement estimate reached the 50^{th} percentile. Run timing, including the date each escapement reached the 1^{st}, 50^{th}, and 99^{th} percentile, was estimated as the cumulative daily escapement divided by total escapement. Run duration was estimated as the number of days elapsed between the 1^{st} and 99^{th} percentile of the total escapement.

Variance was estimated by considering tower counts as a systematic sample and then applying relevant methods developed for such sampling designs (see Reynolds et al. 2007). Variance estimator '5' in Wolter (1984) was used because of its robustness against underlying autocorrelation, stratification, and nonlinear trends (Reynolds et al. 2007). To estimate variance, the seasonal mean count per observation period was calculated, expanded to a mean hourly count based on observation period length and number of hours observed per day, and then multiplied by the number of days in the observation season (see Woody 2004).

Lake Clark Sockeye Salmon Age and Size Composition

Age and size composition of the Lake Clark escapement were determined by sampling pre-spawning sockeye salmon from the subsistence fishery in Sixmile Lake and by sampling post-spawning fish from Lake Clark spawning areas, including Tazimina River, using seines (Figure 3, Appendix 1). Otoliths were extracted and ages were determined by a contracted professional reader (Brenda Rogers, Seattle, Washington) or trained NPS personnel. Lengths were measured from mid-eye to hypural plate (MEH) in millimeters. To make these data comparable with to mid-eye to fork lengths (MEF) collected by ADFG, MEH measures were converted to MEF estimates using regression equations derived by Woody (2004). These equations were derived from 1005 paired measures of MEH and MEF collected in 2000 and 2001.

The conversion equation for females ($r^2 = 0.96$; SE = 8.32) was:

$$MEF = 25.95 + 1.07 * MEH \tag{1}$$

The conversion equation used for males ($r^2 = 0.96$; SE = 8.1) was:

$$MEF = 27.8 + 1.06 * MEH \tag{2}$$

Chi square tests ($\alpha = 0.05$) were used to test for differences in age composition among sockeye samples from Lake Clark spawning areas including the Tazimina River, the Sixmile Lake subsistence fishery, and Tazimina River spawning area. When sample sizes were below 10 in the chi square comparison, that category was dropped from the age analysis.

Intra-annual sizes at age and by sex were compared for samples from the subsistence fishery and Lake Clark spawning areas using Kruskal-Wallis one-way ANOVA on ranks ($\alpha = 0.05$); Dunn's method was applied when the test was significant (Zar 1984).

Environmental and Hydrological Observations

Surface water temperature and stream discharge data were collected at the Newhalen River counting towers. Water temperature was recorded every two hours during escapement monitoring with a Stowaway Tidbit temperature logger (Onset Computer Corporation, Bourne, Massachusetts) and an average daily water temperature was calculated. Staff gauge measurements at the counting tower site were used to estimate stream discharge in the Newhalen River as described by Poe and Rogers (1984). The regression equation derived by Poe and Rogers (1984) used to calculate equivalent stage height/discharge at the USGS gage on the Newhalen River was:

$$Y = .9759 + .8143(x) \tag{3}$$

RESULTS

Lake Clark Sockeye Salmon Escapement

Lake Clark escapement during 2004 – 2007 averaged 592,059 fish, ranged from 445,620 to 700,524 fish, and contributed, on average, 19% of the total Kvichak River escapement (Figure 4, Table 1). Compared to past escapement estimates, the 2004 – 2007 mean escapement was 274% higher than the 2000 – 2003 mean (215,922), and 48% lower than the 1980 – 1984 mean (1,135,464) (Figure 5, Appendix 2).

Sockeye salmon escapement into Lake Clark began around July 1, ended by the middle of August, and lagged behind the Kvichak River escapement by 10 to 18 days (Figures 4-10, Appendices 3-6). Run timing was similar among study years except for 2006 when the run was approximately six days later than average (Figure 6). Mean run duration was 27 days and ranged from 25 to 30 days (Figure 11). During each year, about 90% of the salmon migrated upstream past the left bank tower, and peak migration occurred between the hours of 0800 and 2000 (Figure 12, Appendix 7).

Lake Clark Sockeye Salmon Age and Size Composition

On average, 1,520 sockeye salmon were sampled annually from the local Sixmile Lake subsistence fishery and from Lake Clark spawning areas (Table 2). The age composition of fish within the combined subsistence fishery and spawning area sample for all years was 45.9% age 1.2, 38.1% age 1.3, 10.8% age 2.2, and 5.3% age 2.3.

The age composition of Sixmile Lake subsistence fishery samples were significantly different ($p<0.05$) from Lake Clark spawning area samples for all years except 2005 and for the Tazimina River samples for all years except 2006 (Figure 13, Table 2). For subsistence samples, age-2.2 fish were most abundant in 2004 (58.1%), age-1.3 fish were most abundant in 2005 (64.0%), and age-1.2 were most abundant in 2006 (77.7%) and 2007 (80.3%). For spawning area samples, age-1.2 fish were most abundant in 2004 (59.5%) and 2007 (54.4%), while age-1.3 fish were most abundant in 2005 (64.0%) and 2006 (51.4%).

The median MEF length of all 6,079 sampled sockeye salmon was 537 mm, and annually ranged from 524 mm in 2007 to 565 mm in 2005 (Table 3). Sockeye salmon of the same age sampled from the subsistence fishery were significantly larger ($p<0.05$) than those of the same age salmon sampled from Lake Clark spawning areas, and males were significantly larger ($p<0.05$) than females. Annual length frequency distributions for combined samples were similar for 2004, 2006, and 2007, while the distribution for 2005 was shifted towards larger fish and more evenly spread over a greater range of sizes (Figure 15). Median MEF lengths for age-1.2 and -2.2 fish were generally similar among sample years and sample locations, but age-1.3 and -2.3 fish captured at spawning areas were generally smaller each year since 2004 (Figures16-19).

Environmental and Hydrological Observations

Water temperature and stream discharge during the operation of the Newhalen River counting tower for all years ranged from 6.5 to 15.5° C (average, 11.3° C) and 13,530 to 23,170 ft^3/sec (average, 21,090 ft^3/sec) (Appendix 8). Average water temperature was highest in 2004 (12.8° C; range: 7.3 to 15.5° C) and lowest in 2006 (9.4° C; range: 6.5 to 11.8° C). Average stream discharge was greatest in 2005 (21,369 ft^3/sec; range: 19,180 to 22,510 ft^3/sec) and lowest in 2007 (15,748 ft^3/sec; range: 13,530 to 17,230 ft^3/sec). Over the course of the counting season, water temperatures tended to increase while steam discharge tended to decreased (Figures 20 and 21). However, 2007 was anomalous since stream discharge was not only low but tended to increase over the course of the season. Generally, daily sockeye salmon escapements appeared more related to fluctuations in daily water temperatures than stream discharge.

DISCUSSION

The overall decrease in Lake Clark sockeye salmon escapements for 2000 – 2007 as compared to 1980-1984 (Figure 5, Appendix 2) is not a sampling artifact. Our data should be directly comparable to that collected by Poe and Rogers (1984) and Woody (2004) because the same tower sites, protocols, and some of the same personnel were used. We also feel that the recent increase in mean escapement for 2004-2007 as compared to 2000-2003 was real since a similar increase in mean escapement was also documented for the total Kvichak River system escapement, which increased by 258% since 2004 (Sands et al. 2008). While Lake Clark sockeye salmon escapement estimates do not extend as far back in time as those for the entire Kvichak River system, a rough approximation of the potential range of Lake Clark escapements during that same period can be obtained by assuming these escapements have represented a constant annual contribution to the total Kvichak River system escapement. This assumption is based on the similarity of Lake Clark's annual contributions among all study years (1980 – 2007; Poe and Rogers 1984, Woody 2004), which ranged from 7 to 29%. Applying the mean Lake Clark contribution of 18 % to the historic range (200,000 to 4,600,000), mean (5,200,000), and median (3,600,000) of Kvichak River escapements for the period 1955-2007 (Anderson 2000, Fair 2003, Morstad and Baker 2006, ADFG 2009), resulted in an estimated Lake Clark escapement range of 36,000 to 4,374,000, a mean of 936,000, and a median of 648,000 sockeye salmon. While actual 2004 – 2007 Lake Clark escapements were within the estimated historical range, they were all well below the estimated historical mean and median values.

The decline in Lake Clark sockeye salmon escapements observed between the 2000 – 2007 and 1980 – 1984 was associated with an overall decline in Bristol Bay sockeye salmon production since the 1990s that appears to be linked to decadal-scale climate variations in the North Pacific Ocean (Miller et al. 2004, Mantua et al. 1997). Generally, Alaska salmon stocks production tends to increase and decrease in response to the alternating warm and cold phases of sea surface temperatures referred to as the Pacific Decadal Oscillation (PDO), which is controlled by and in phase with decadal changes in the Aleutian Low. The PDO was in a warm phase from about 1977 through about 1998, and then switched to a cool phase. PDO effects are likely most important for Bristol Bay sockeye salmon stocks during their first two years at sea since adult abundance is positively correlated with marine growth during this period (Ruggerone et al. 2007). Additionally, changes in abundance of the Kvichak stock are positively correlated with the age-specific length of parents and negatively correlated with sea-surface temperatures during the time adults are returning to spawn (Ruggerone and Link 2006). Since the current PDO cool phase only began in the late 1990s, it will probably persist through 2020 or later. Therefore, recent increases in Lake Clark escapements have probably largely been due to commercial and sport fisheries restrictions and closures as a result of the State's designating Kvichak River sockeye salmon a stock of concern (Morstadt and Baker 2006) rather than improved ocean survival.

The later run time for the Lake Clark stock in 2006 (Figure 10) was similar to the run timing for other east side Bristol Bay stocks (Salomone et al. 2007) and other stocks throughout the state (e.g., upper Cook Inlet; Shields and Willette 2008) and may have been caused by colder than average water temperatures. Colder than normal sea surface temperatures during April – May may have delayed migration as this situation tends to be correlated with later migration timing (Hodgson et al. 2006). Similarly, colder than normal surface water temperatures in the Newhalen River in 2006 may explain the longer travel time estimated for sockeye salmon between the Kvichak and Newhalen rivers counting sites.

Since 2000, the annual duration of the Lake Clark run has been relatively constant and less variable than was documented during the 1980s (Poe and Rogers 1984). Many factors can affect upstream salmon migration including natural migration barriers, water temperature, water discharge, fish size, light, water quality, time of season, and catch and handling stress (Banks 1969, Quinn 2005, Thorstad et al. 2008). For the Newhalen River, the rapids and falls at river kilometer 11 can delay or block upstream migration during times of high water discharge. Peak summer flows recorded during 2004 – 2007 were generally lower than the flows measured by Poe and Rogers (1984) and well below the extremely high flows of 1980 (28,000 – 32,568

ft^3/sec) that created a velocity barrier for upstream passage of sockeye salmon. Water temperatures were similar to those recorded at this site in the 1980s (Poe and Rogers 1984) and similar to those recorded in other sockeye salmon systems (Hodgson and Quinn 2002).

Patterns in bank orientation and diurnal migration were similar to past observations at the Newhalen River site and at other sites within Bristol Bay (Becker 1962, Poe and Rogers 1984, Anderson 2000, Woody (unpublished data). On average, counts at night between the hours of 0000 and 0400, comprised less than 4% of the total daily escapement, which was similar to the migration patterns observed by Poe and Rogers (1984).

Differences in age composition and size-at-age for samples collected from the subsistence fishery and from Lake Clark and Tazimina River spawning areas suggest sampling biases exist and fishery samples were not representative of the escapement passing the Newhalen River counting site (Figure 14, Tables 2). This is probably due to the fact that not only does the subsistence fishery generally harvest sockeye salmon that are larger-at-age than those in the total population passing the tower site, but also harvest a larger proportion of sockeye salmon bound for the Tazimina River (Figure 3, Table 2). Sockeye salmon that spawn in Lake Clark and its tributaries generally migrate quickly through Sixmile Lake (Young and Woody 2007b), but those that spawn in Tazimina River may remain in Sixmile Lake three to four weeks before resuming their migration upstream (Woody 2004). Since subsistence samples collected by Woody (2004) and during this study do not appear to be representative of the age and size at maturity of the total population passing the tower site, samples from the subsistence fishery and spawning areas should be weighted by abundance to produce a less biased estimate for the age and size composition of the total population.

The age and size of the Sixmile Lake subsistence fishery samples were similar to those reported by Woody (2004), but different than samples collected during the early 1980s (Benolkin 2009). Samples collected from the subsistence fishery during 2001 – 2007 had a greater proportion of male and female sockeye salmon that spent three years in the ocean (1.3 and 2.3) compared to samples collected during 1979 – 1985. Also, both male and female sockeye salmon, within each age class, were smaller in length during 2001 - 2007 than during 1979 – 1985 (Benolkin 2009). The increase in age and decrease in size is consistent with what has been documented for other Pacific salmon stocks (Ricker 1981, 1982, 1995; Helle and Hoffman 1995; Ishida et al. 1995; Bigler et al. 1996). Possible hypotheses proposed to explain changes in age and size of salmon include changes in the ocean environment (temperature, upwelling, salinity), genetics (through selective fisheries), increased salmon abundance (increased competition for food), and statistical artifacts (Ricker 1980, Burgner 1991, Quinn 2005). For the Lake Clark population, changes in the ocean environment including increases in summer/winter sea surface temperatures and increased summer upwelling/decreased winter upwelling appear to influence fish (Benolkin 2009). It is also likely that a combination of other factors including salmon abundance and the size selective commercial and subsistence fisheries are determining fish size for the Lake Clark stocks (Benolkin 2009).

CONCLUSIONS

1. The 2004 – 2007 mean escapement of sockeye salmon into Lake Clark was 274% higher than the recent (2000 – 2003) mean of 215,922, but 48% lower than the mean escapement of 1,135,464 during 1980 – 1984.

2. The Lake Clark sockeye salmon escapement comprised, on average, 19% of the total Kvichak River system escapement, which was similar to previous years.

3. Run timing past the Newhalen River counting towers was similar to what was observed during previous years except for 2006 when the run was approximately six days later than average.

4. The mean duration of the run was 27 days and ranged from 25 to 30 days, which was similar to previous years.

5. Samples from Lake Clark spawning areas indicate age 1.2 fish were most abundant in 2004 and 2007 while age 1.3 fish were most abundant in 2005 and 2006.

6. Samples from the subsistence fishery indicate age 2.2 fish were most abundant in 2004, age 1.3 fish were most abundant in 2005, and age 1.2 were most abundant in 2006 and 2007.

7. Overall trends in age composition were different between subsistence fishery and spawning area samples except in 2005, and indicate a bias in fishery samples towards sockeye salmon spawning in the Tazimina River.

8. Sockeye salmon sampled from the subsistence fishery were significantly larger at age than those sampled from spawning areas, and indicated a bias in fishery samples towards larger fish.

9. Differences in age and size composition between subsistence fishery and spawning area samples indicate that these samples should be weighted by abundance to produce less biased estimates of the age and size composition of the total population.

10. Newhalen River surface water temperatures and stream discharge during the study were similar to those recorded in past years and within normal ranges for sockeye salmon passage.

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FIGURES AND TABLES

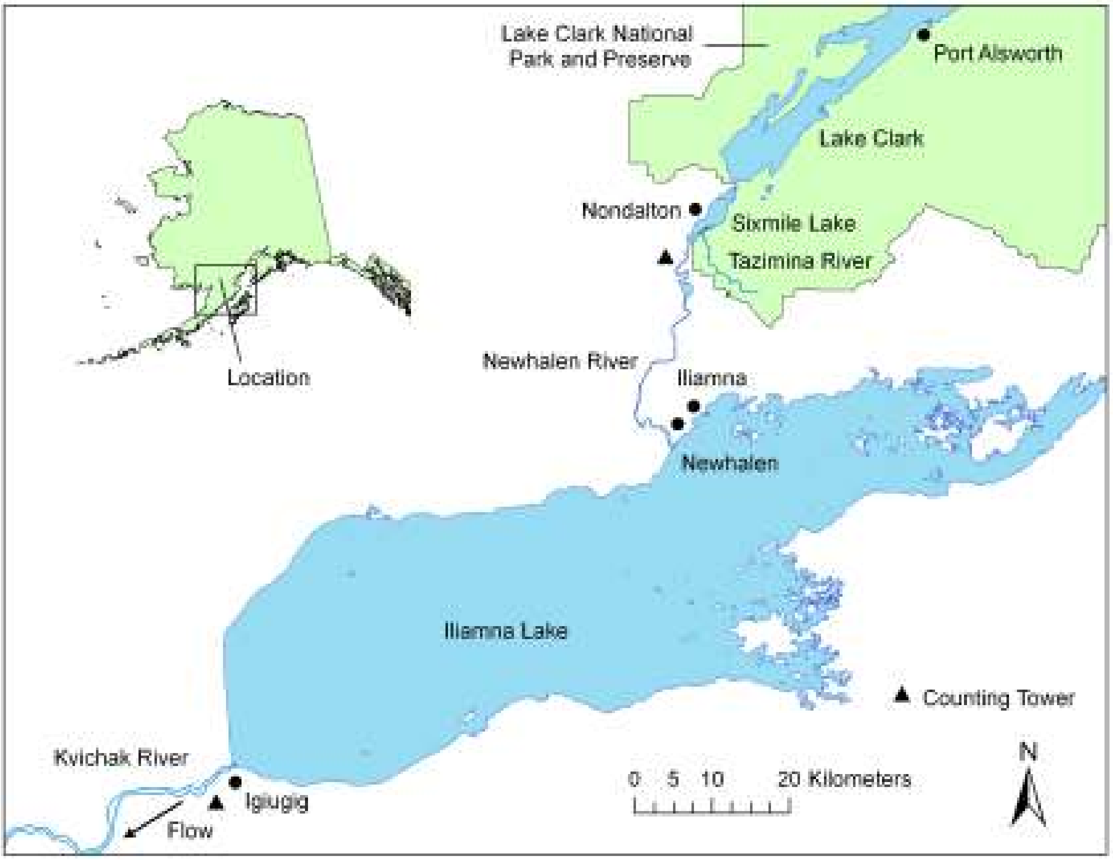

Figure 1. Location of the Kvichak and Newhalen River counting towers within the Kvichak River drainage. The counting tower located near the community of Igiugig is operated by the Alaska Department of Fish and Game.

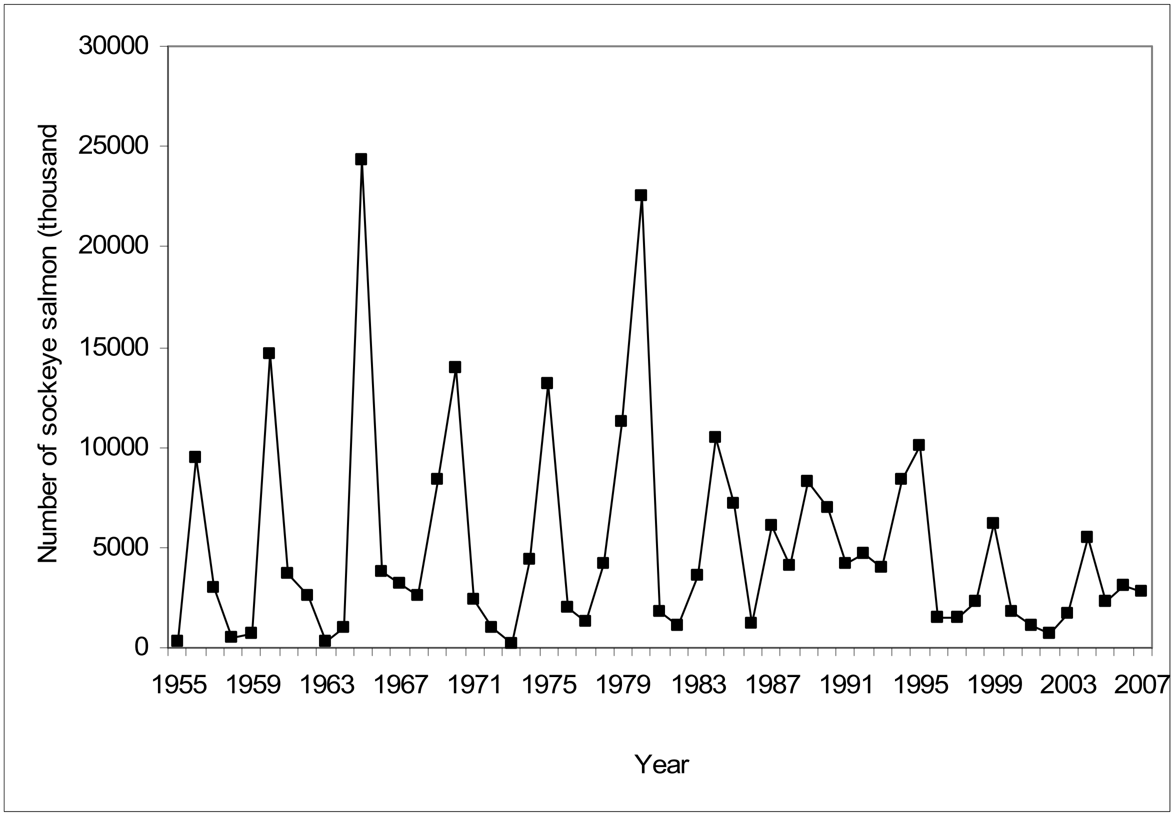

Figure 2. Annual sockeye salmon escapements to the Kvichak River, 1955 to 2007. Data from the Alaska Department of Fish and Game (2009).

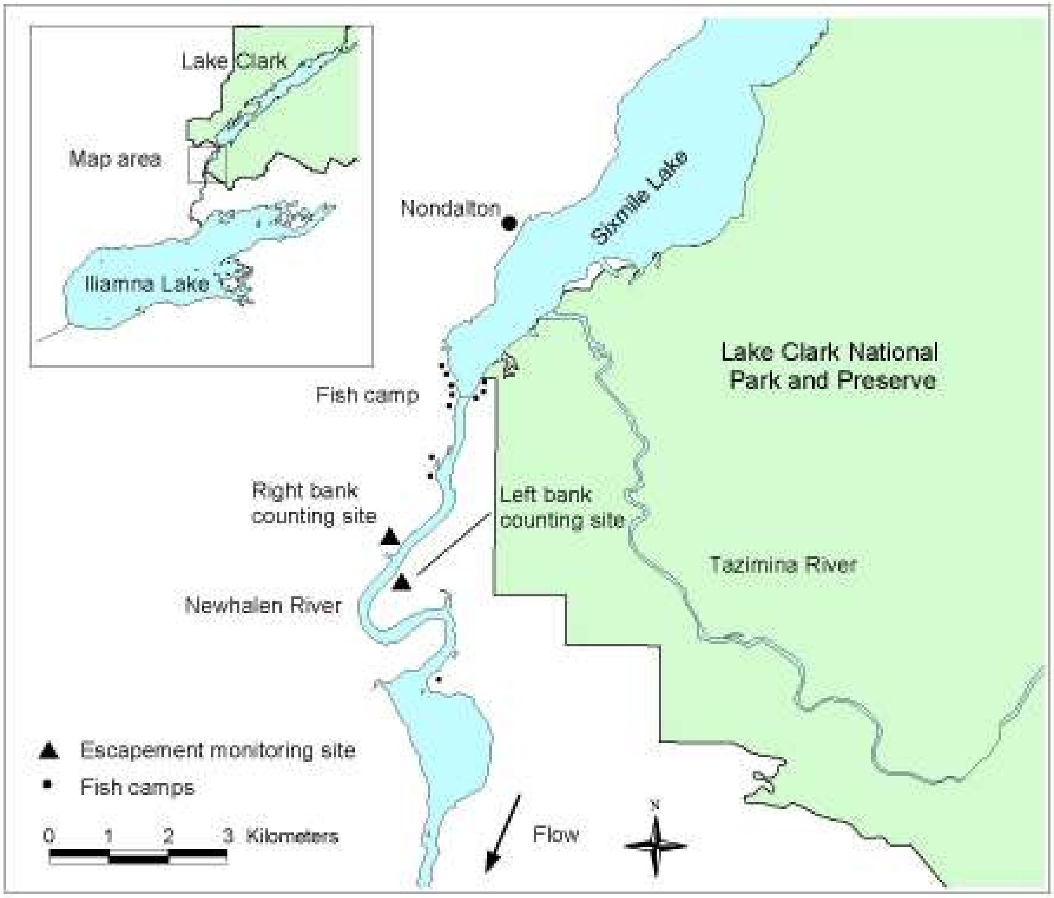

Figure 3. Location of the Newhalen River counting towers.

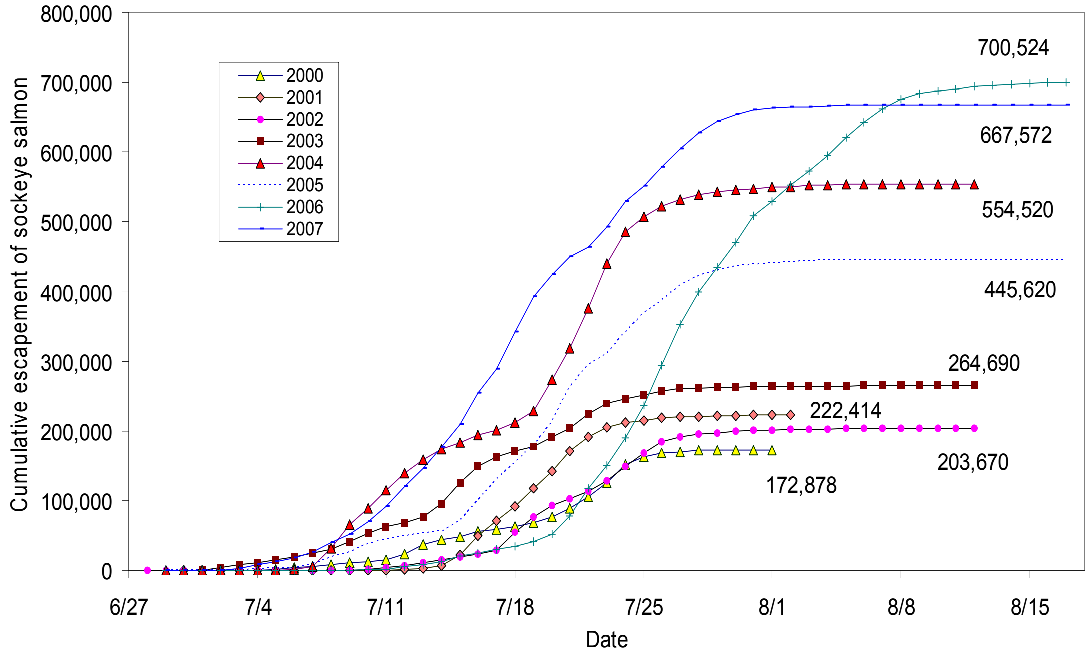

Figure 4. Cumulative escapement of sockeye salmon at the Newhalen River counting tower, 2000 – 2007. Data for 2000 – 2003 from Woody (2004).

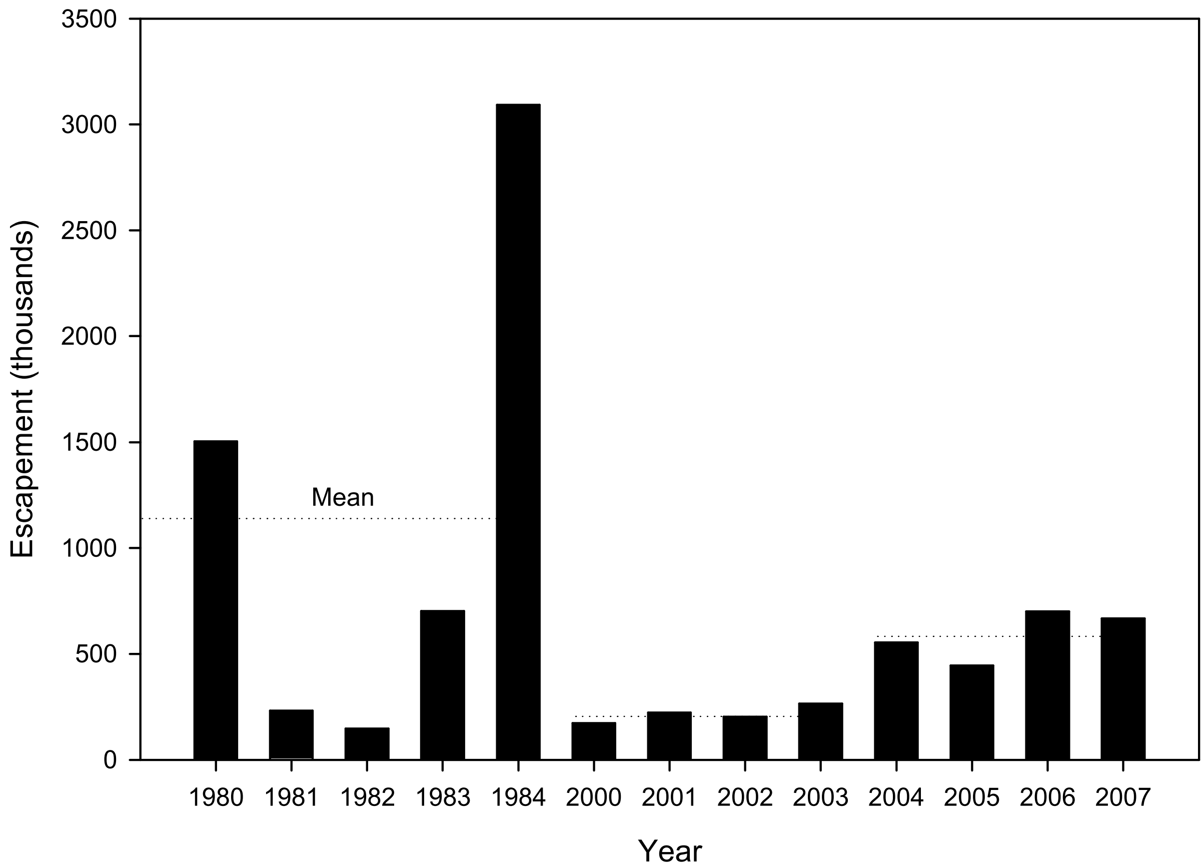

Figure 5. Newhalen River sockeye salmon escapement by year and four or five year means, 1980 – 1984 and 2000 – 2007. Data for 1980 – 2003 from Poe and Rogers (1984) and Woody (2004).

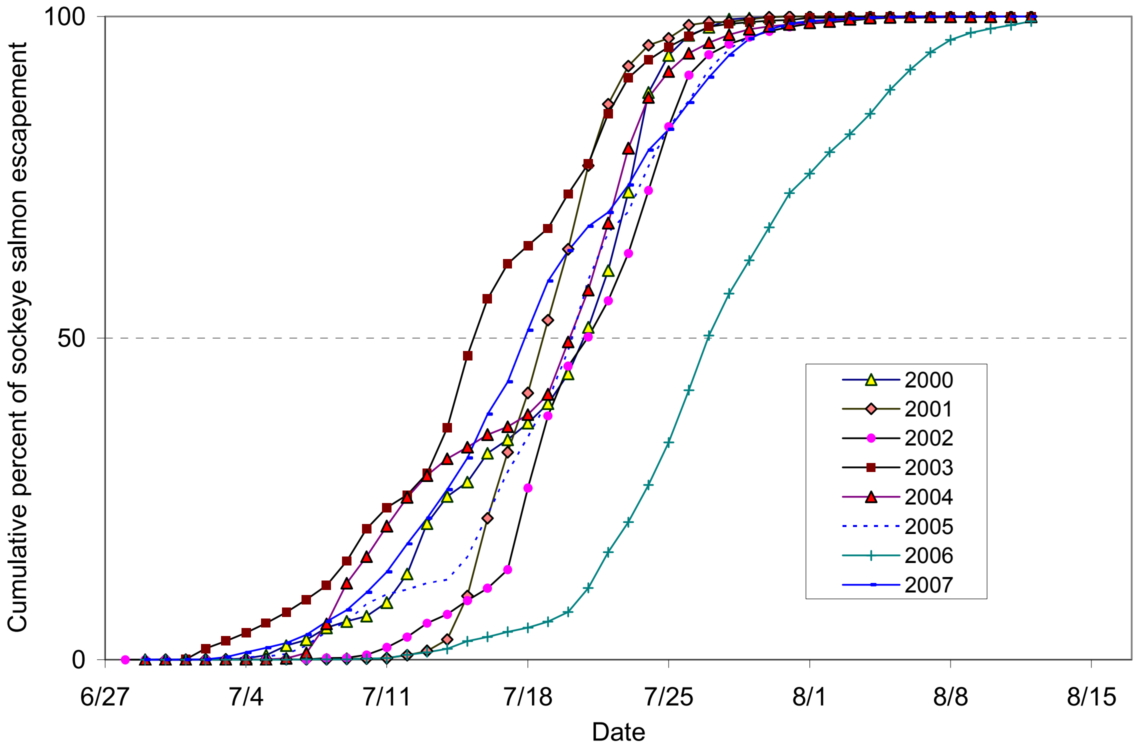

Figure 6. Cumulative percent of total sockeye salmon escapement to the Newhalen River by date, 2000 – 2007. Data for 2000 – 2003 from Woody (2004).

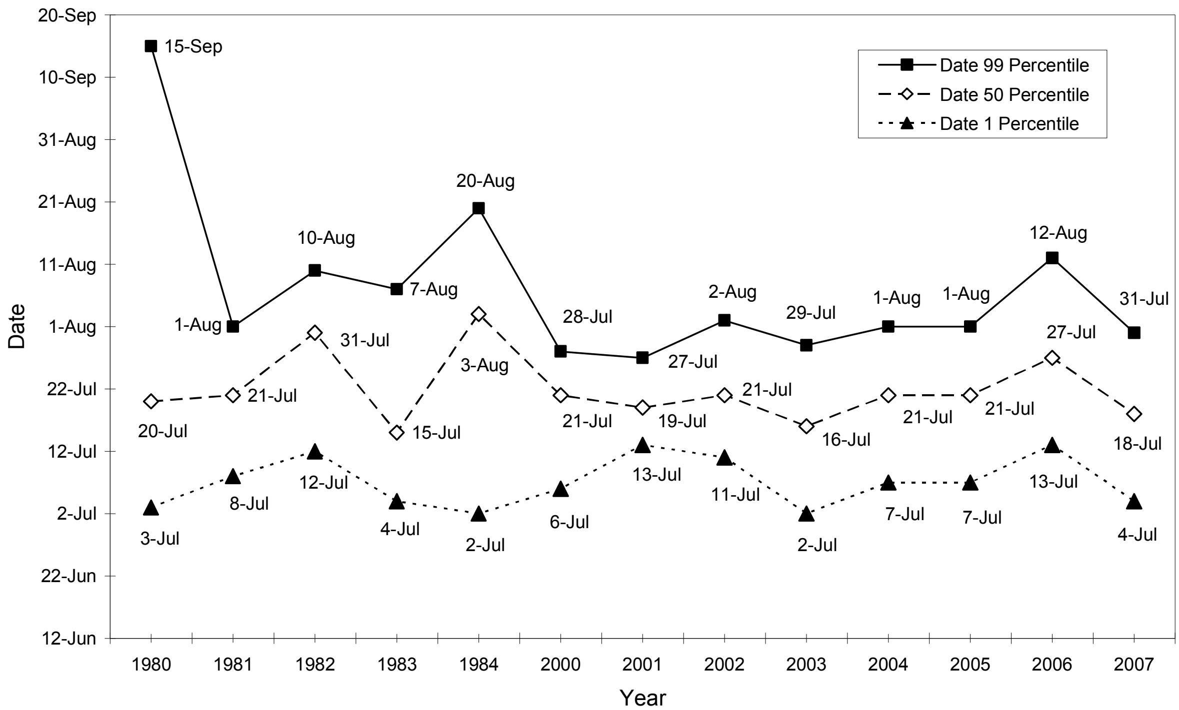

Figure 7. Newhalen River sockeye salmon escapement by year and percentile, 1980 – 1984 and 2000 – 2007. Data for 1980 – 2003 from Poe and Rogers (1984) and Woody (2004).

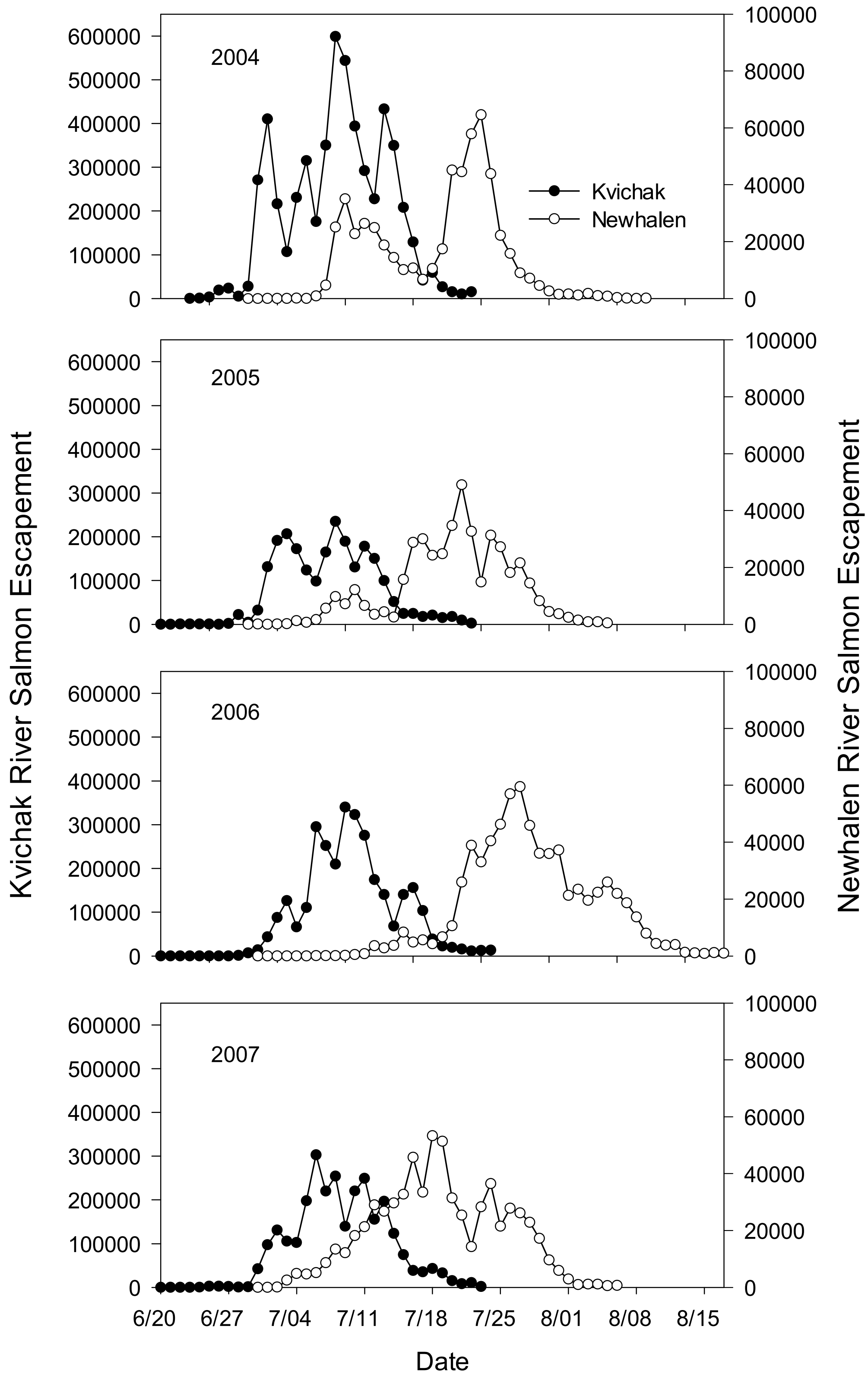

Figure 8. Daily sockeye salmon escapement to the Kvichak and Newhalen Rivers, 2004 – 2007. Kvichak River data from the Alaska Department of Fish and Game (2009).

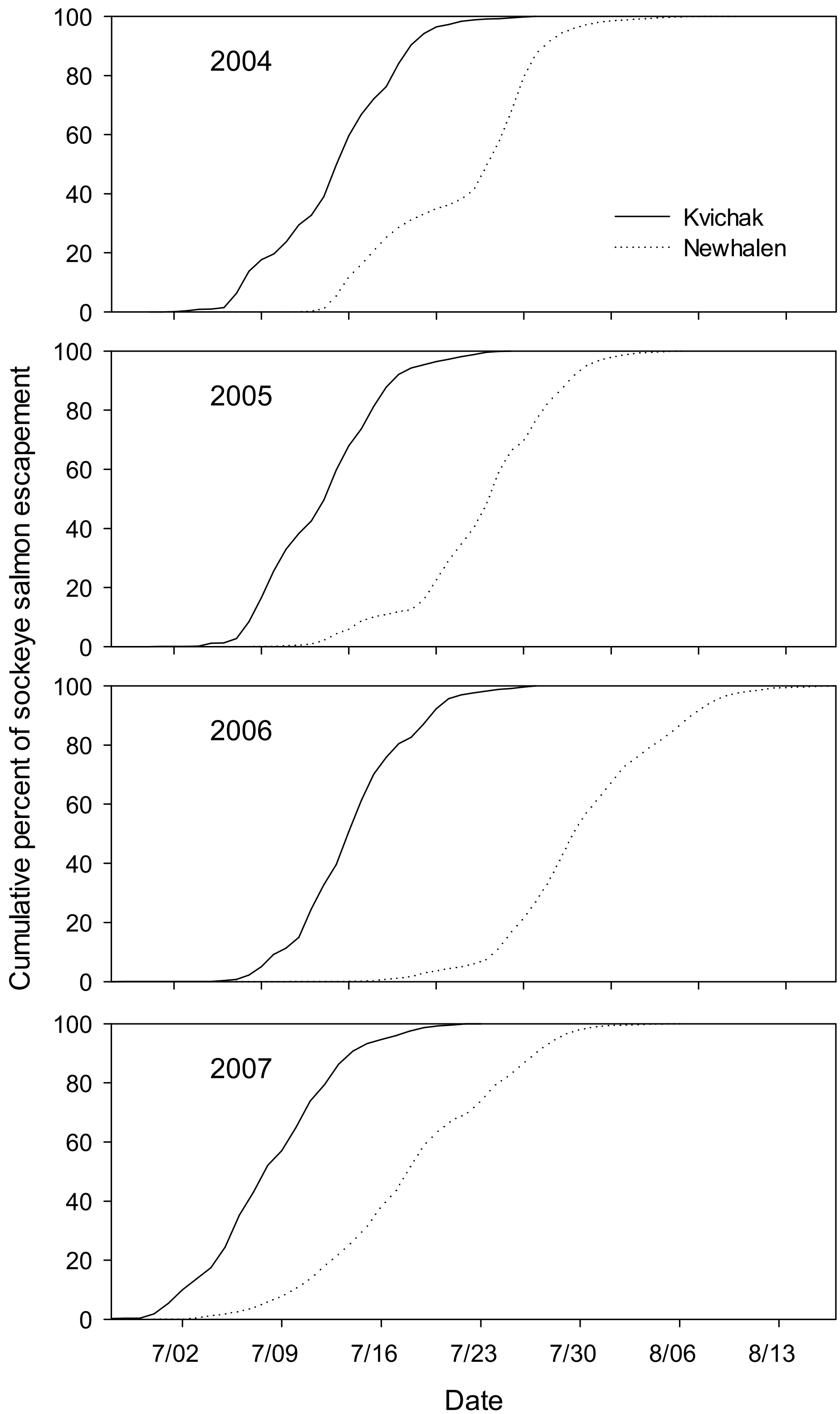

Figure 9. Cumulative percent of total sockeye salmon escapement to the Kvichak River and Newhalen River by date, 2004 – 2007. Kvichak River data from the Alaska Department of Fish and Game (2009).

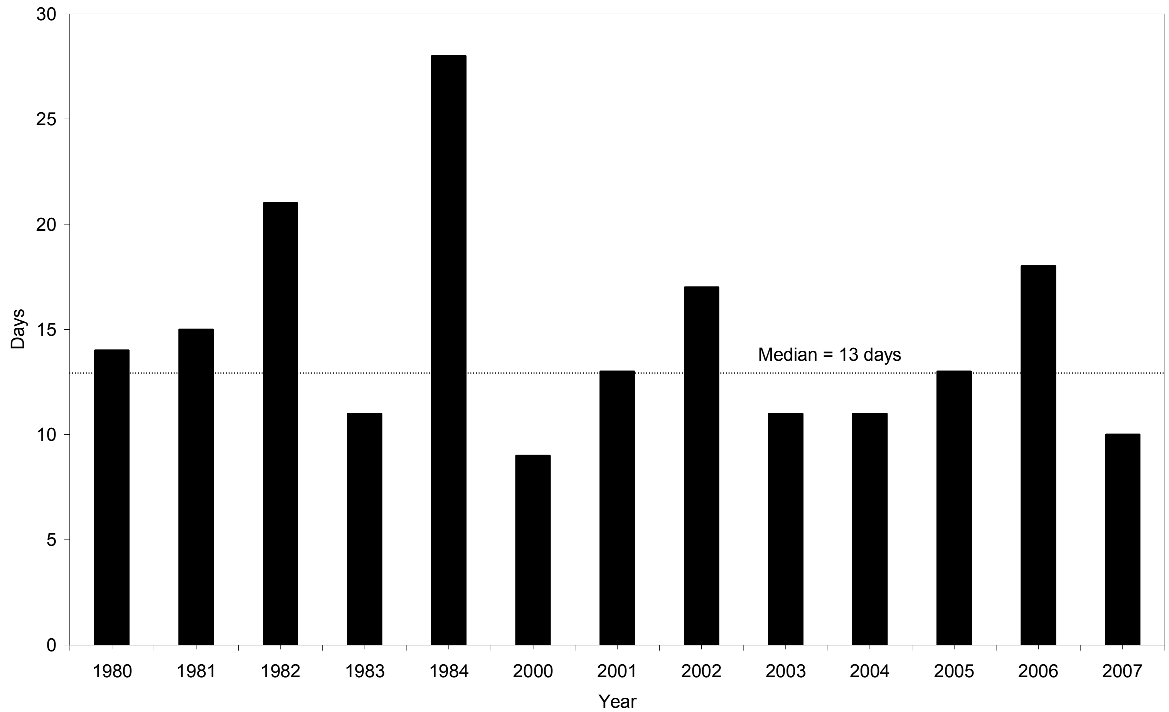

Figure 10. Lag time between the Kvichak River and Newhalen River escapements; estimated by comparing the date when each escapement estimate reached the 50th percentile, 1980 – 1984 and 2000 – 2007. Kvichak River data from the Alaska Department of Fish and Game (2009). Newhalen River data from Poe and Rogers (1984) and Woody (2004).

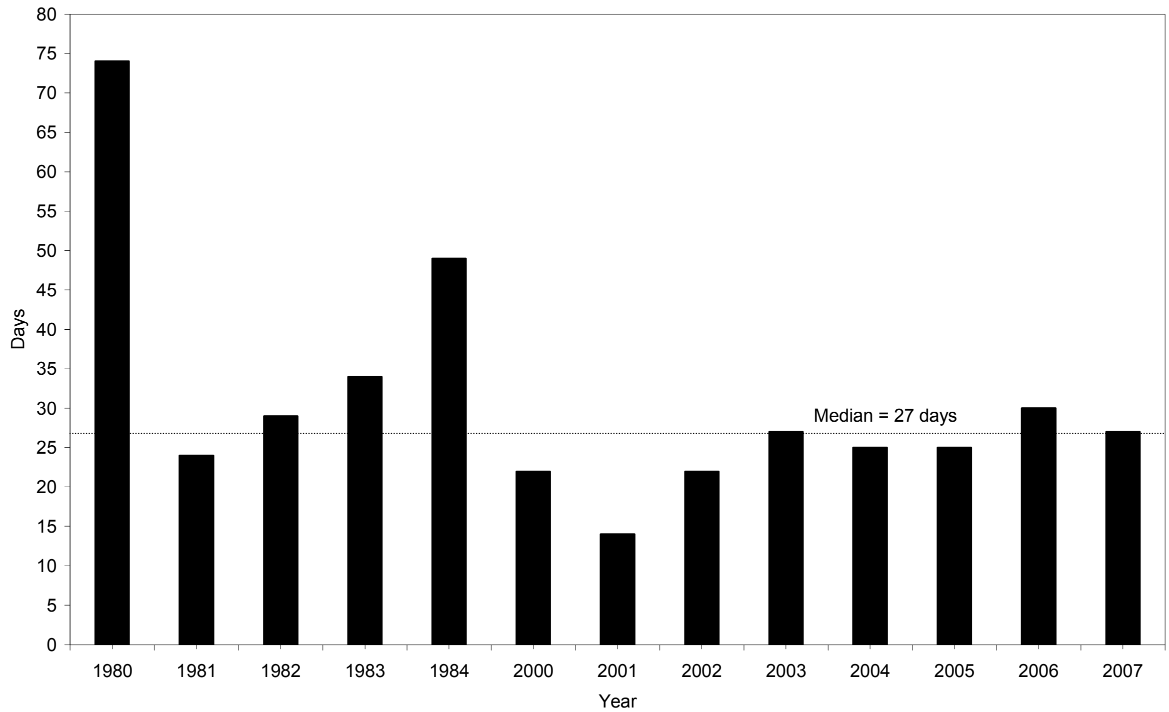

Figure 11. Newhalen River sockeye salmon run duration; number of days between 1st and 99th percentile, 1980 – 1984 and 2000 – 2007. Data for 1980 – 2003 from Poe and Rogers (1984) and Woody (2004).

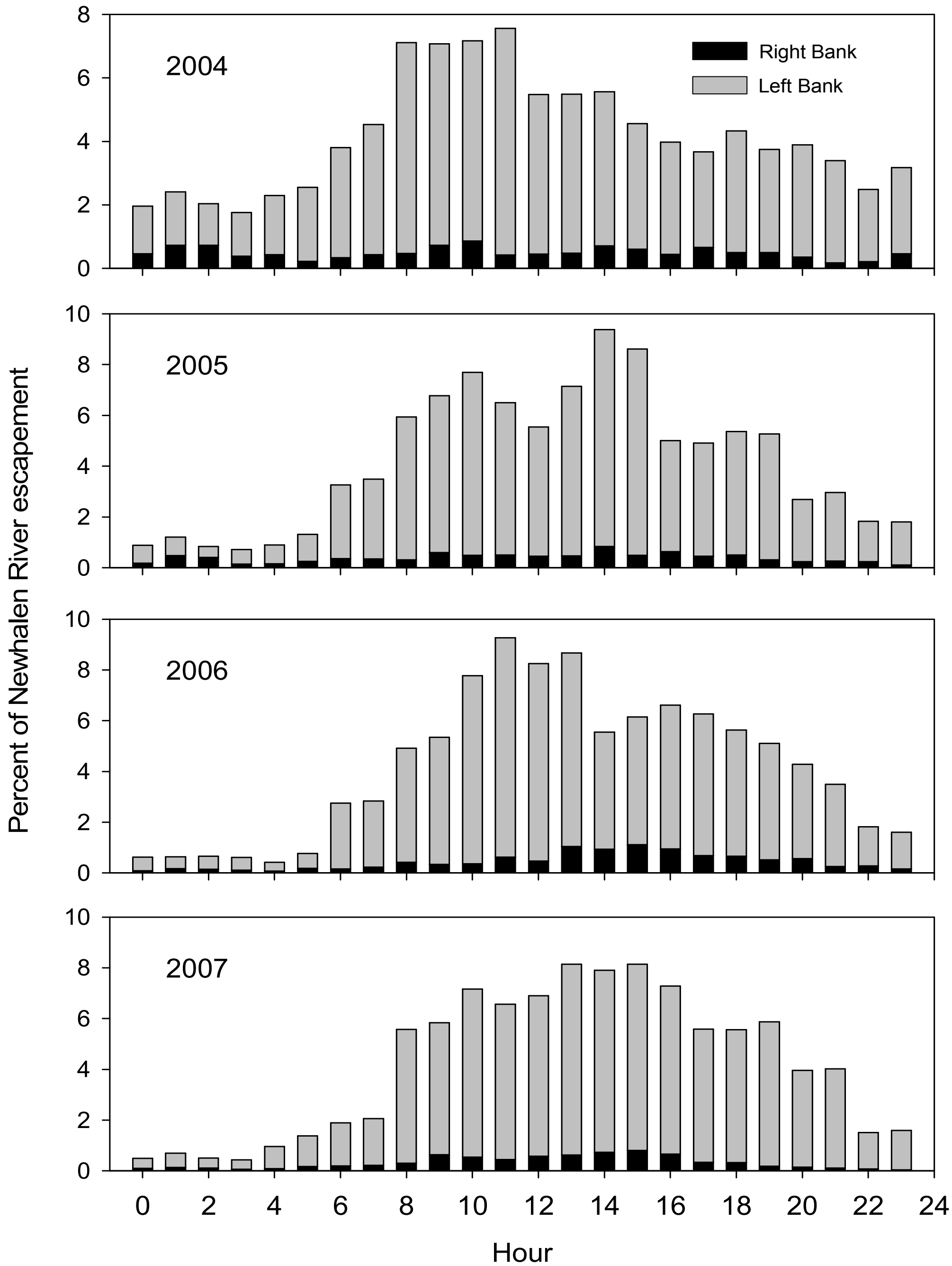

Figure 12. Percent of sockeye salmon counted at the Newhalen River counting towers by hour and bank (looking downstream), 2004 – 2007.

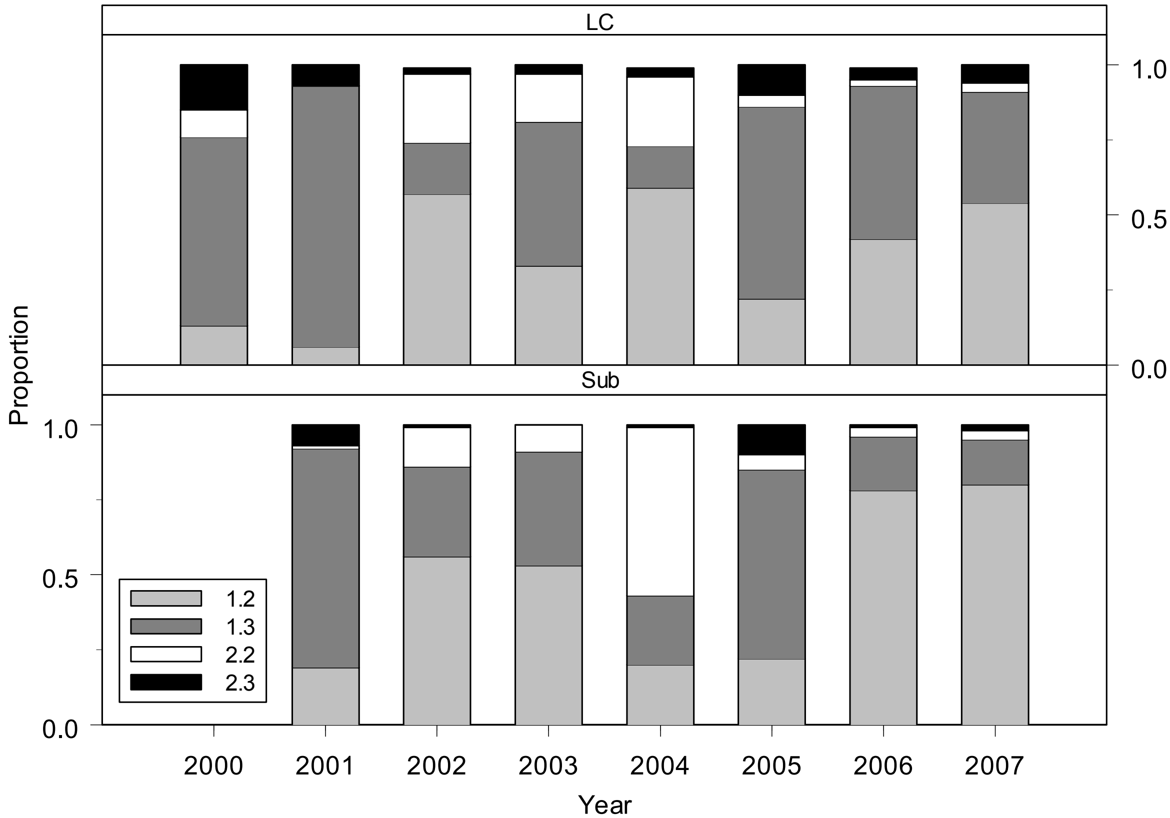

Figure 13. Age composition of sockeye salmon sampled from Lake Clark spawning areas (LC) and the Sixmile Lake subsistence fishery (Sub), 2000 – 2007.

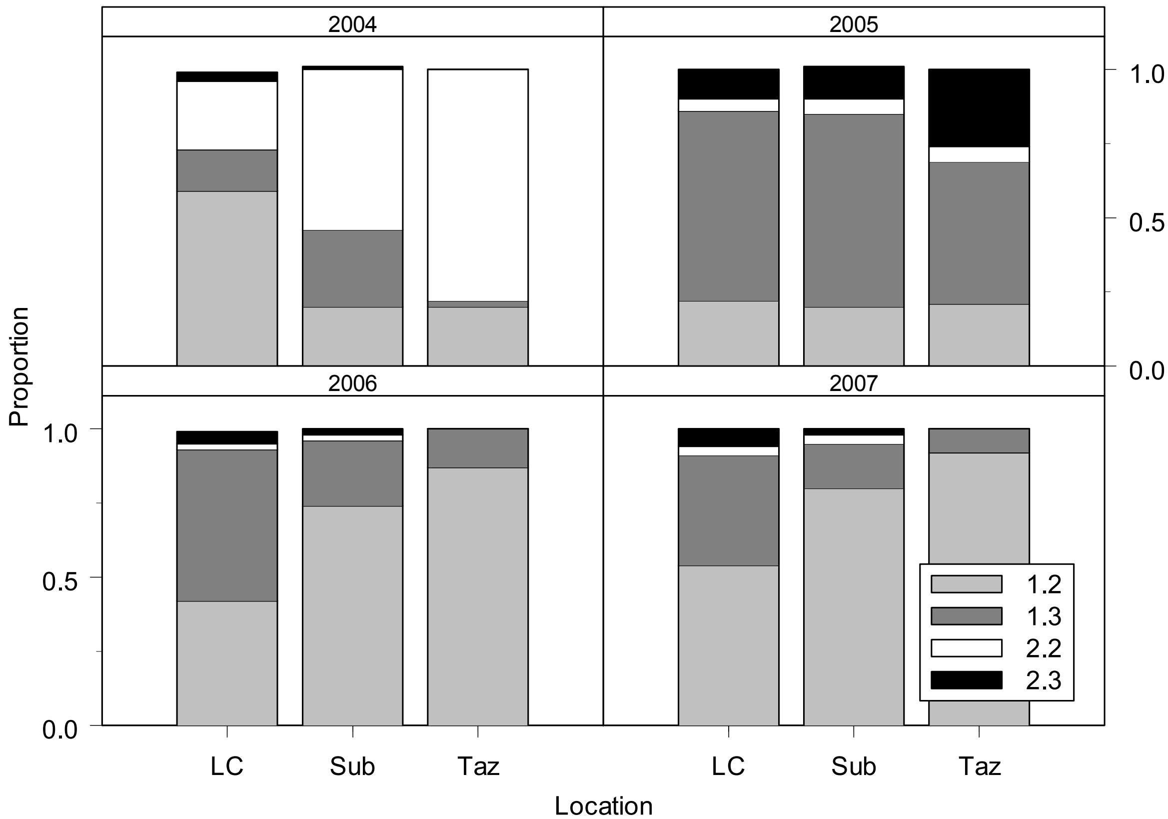

Figure 14. Age composition of salmon captured from the Sixmile Lake subsistence fishery (Sub) and from Lake Clark (LC) and Tazimina River (Taz) spawning areas.

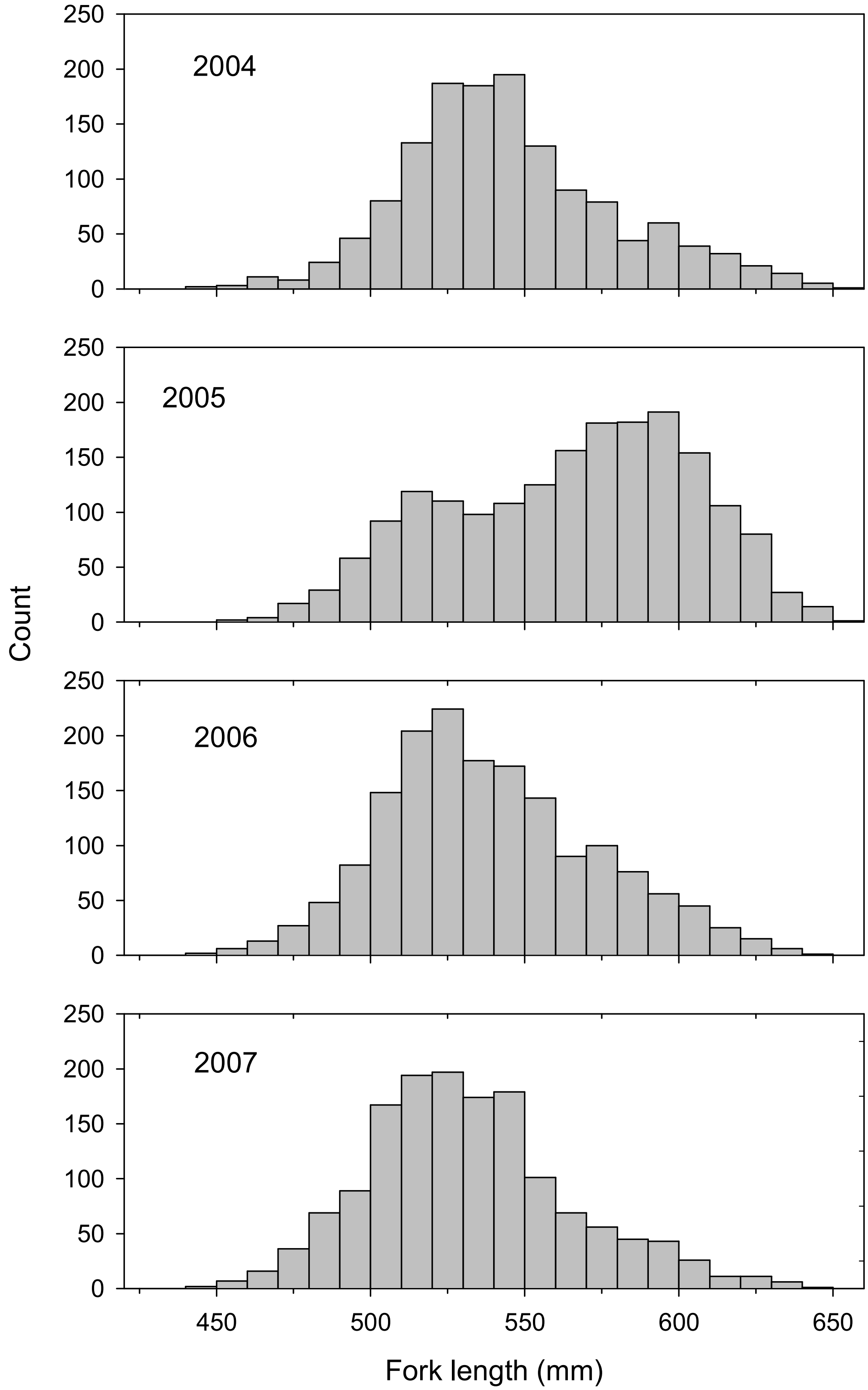

Figure 15. Length frequency distribution of combined sockeye salmon samples obtained from Lake Clark spawning areas and the Sixmile Lake subsistence fishery, 2004 – 2007.

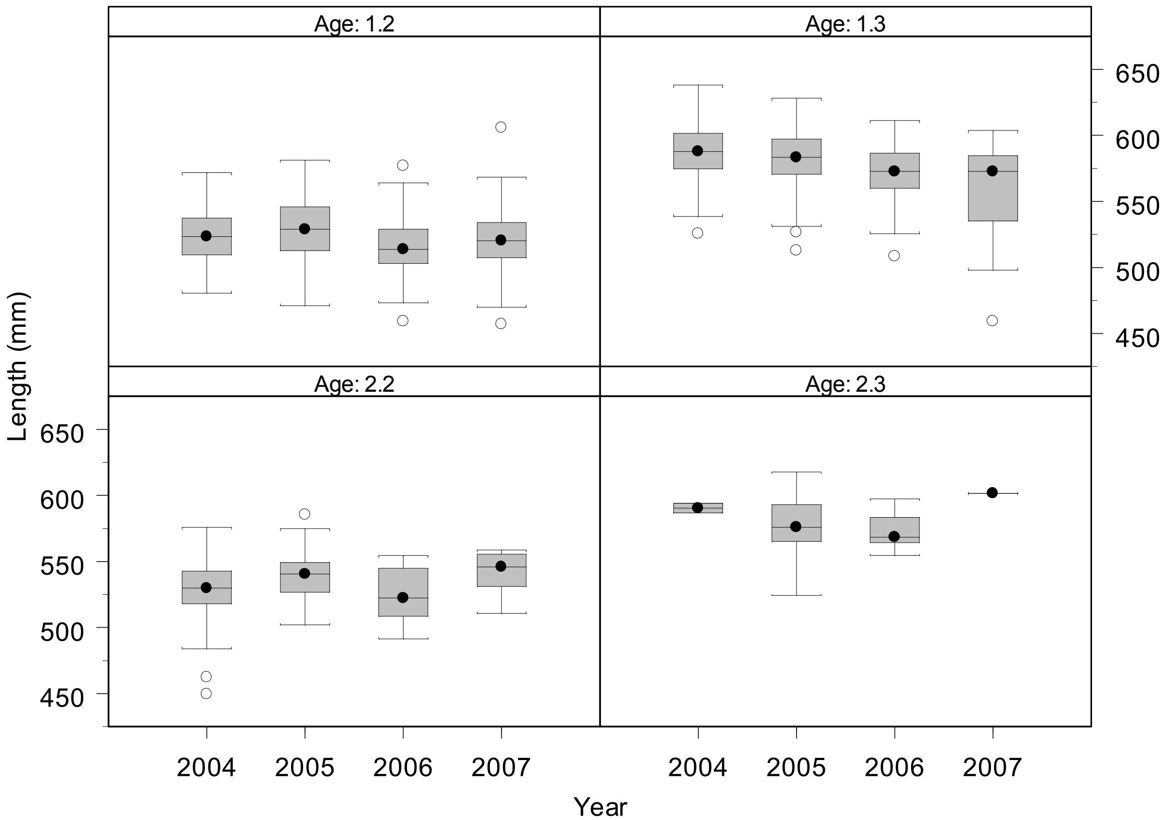

Figure 16. Box and whisker plots of mid-eye to fork length (mm) data from female sockeye salmon samples taken from the Sixmile Lake subsistence fishery, 2004 – 2007. Shaded box = central 50% of data, filled circle within box = median value, lines with horizontal bars = range of data points that are within 1.5 times the interquartile range from either end of the box, ,and open circles = outlier data points that are more than 1.5 times the interquartile range from either end of the box.

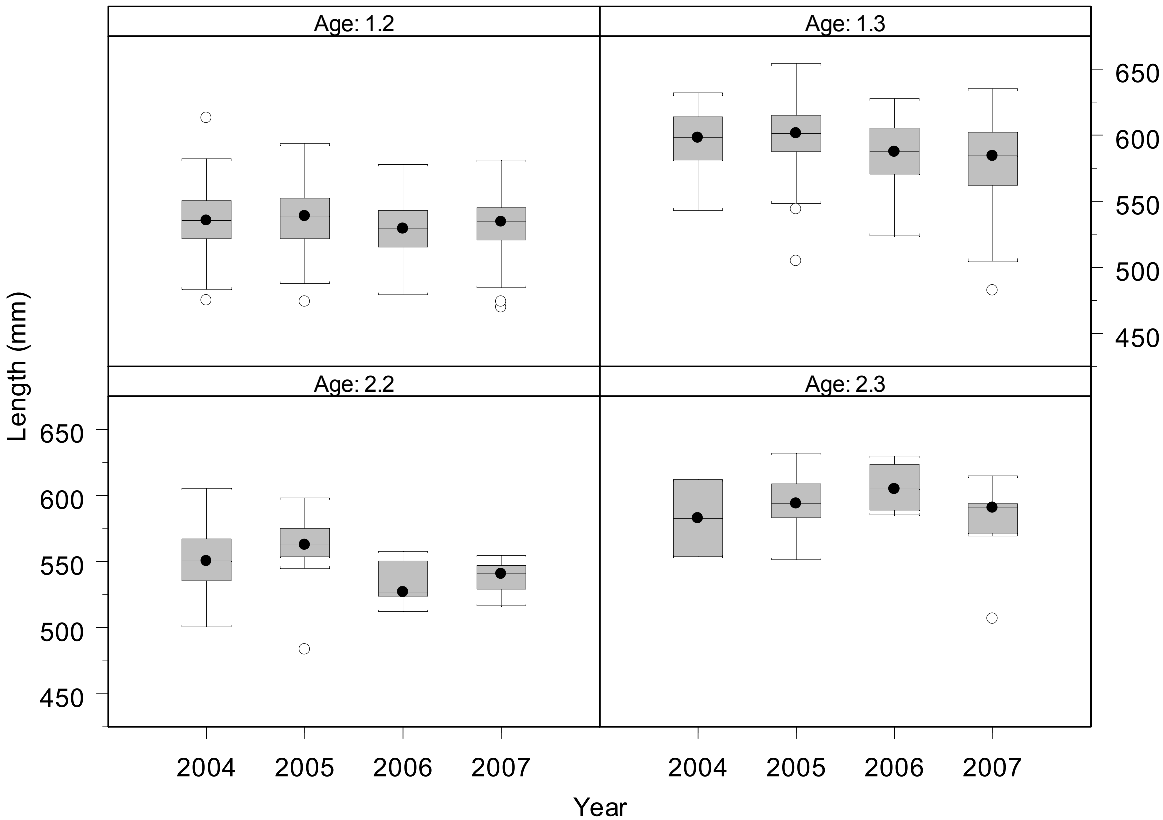

Figure 17. Box and whisker plots of mid-eye to fork length (mm) data from male sockeye salmon samples taken from the Sixmile Lake subsistence fishery, 2004 – 2007. Shaded box = central 50% of data, filled circle within box = median value, lines with horizontal bars = range of data points that are within 1.5 times the interquartile range from either end of the box, ,and open circles = outlier data points that are more than 1.5 times the interquartile range from either end of the box.

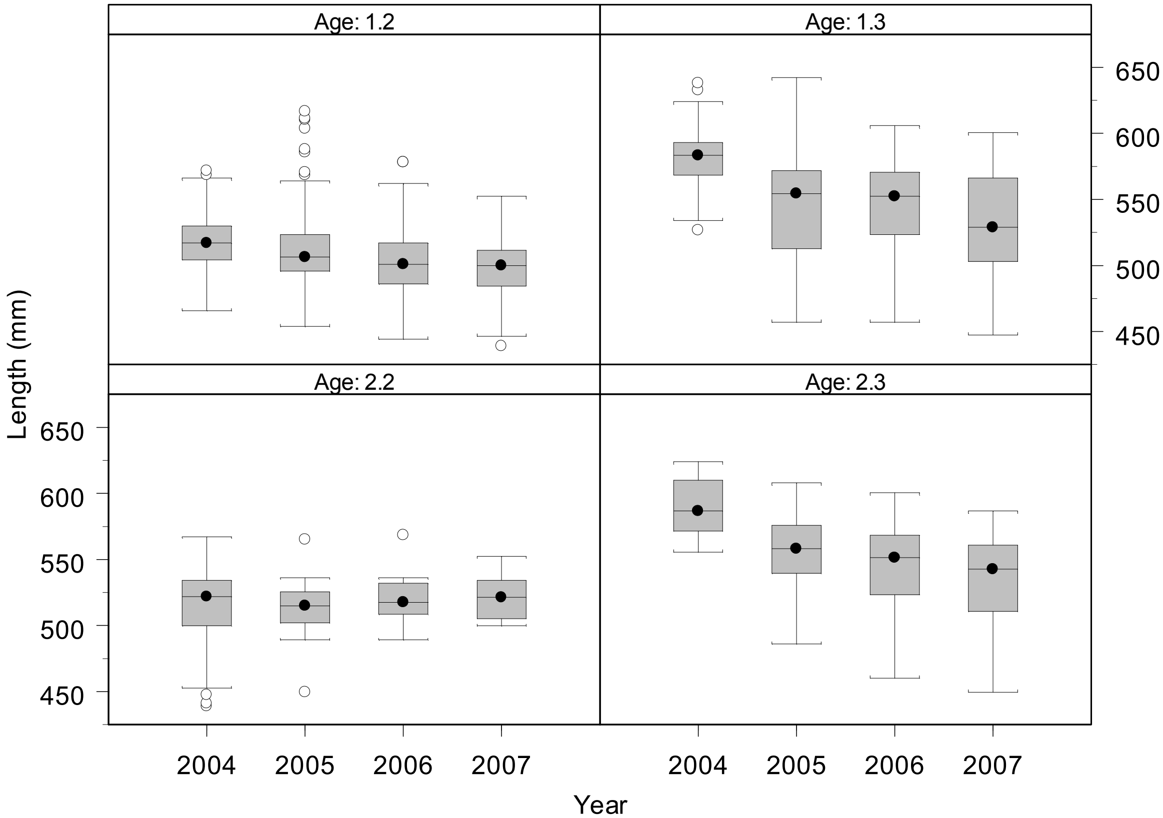

Figure 18. Box and whisker plots of mid-eye to fork length (mm) data from female sockeye salmon samples taken from Lake Clark spawning areas, 2004 – 2007. Shaded box = central 50% of data, filled circle within box = median value, lines with horizontal bars = range of data points that are within 1.5 times the interquartile range from either end of the box, ,and open circles = outlier data points that are more than 1.5 times the interquartile range from either end of the box.

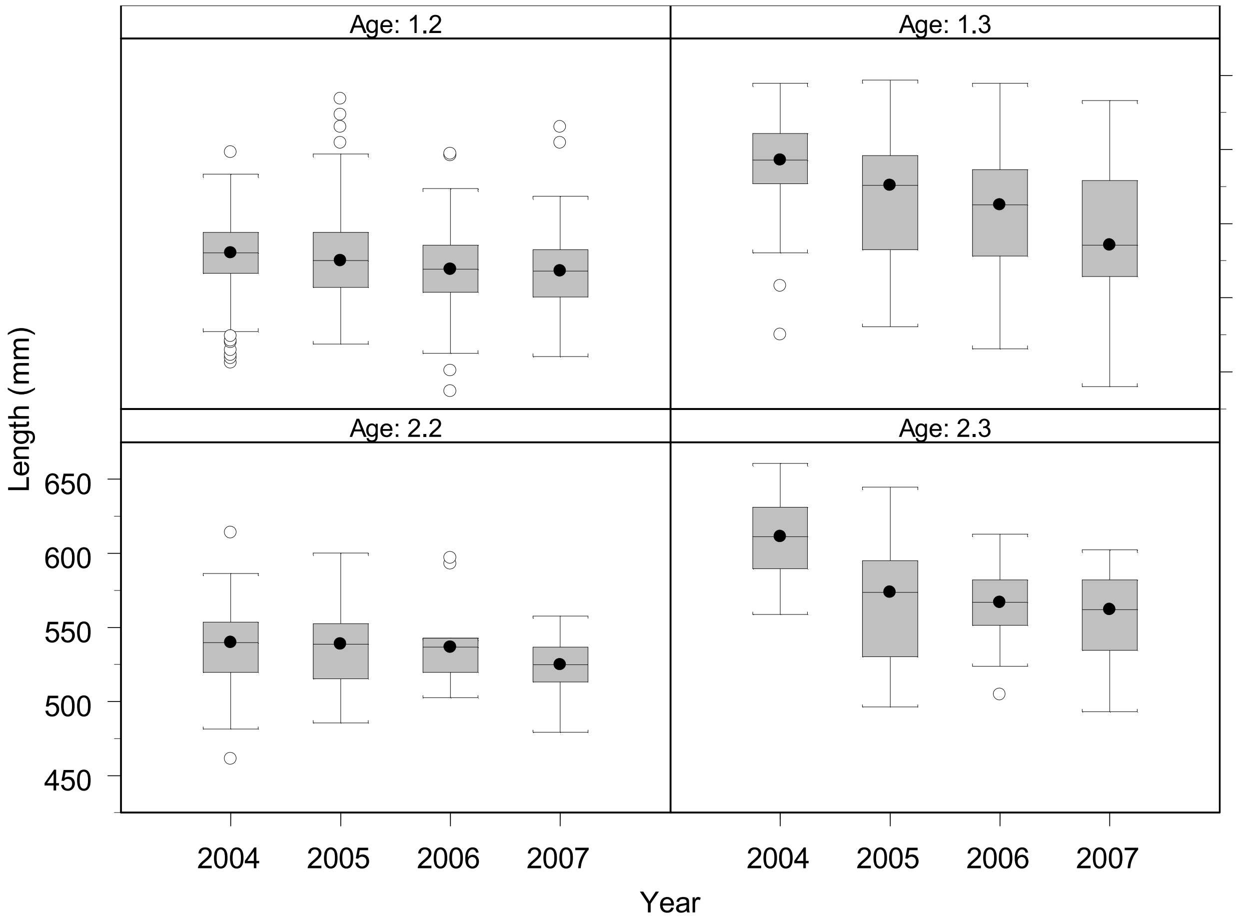

Figure 19. Box and whisker plots of mid-eye to fork length (mm) data from male sockeye salmon samples taken from Lake Clark spawning areas, 2004 – 2007. Shaded box = central 50% of data, filled circle within box = median value, lines with horizontal bars = range of data points that are within 1.5 times the interquartile range from either end of the box, ,and open circles = outlier data points that are more than 1.5 times the interquartile range from either end of the box.

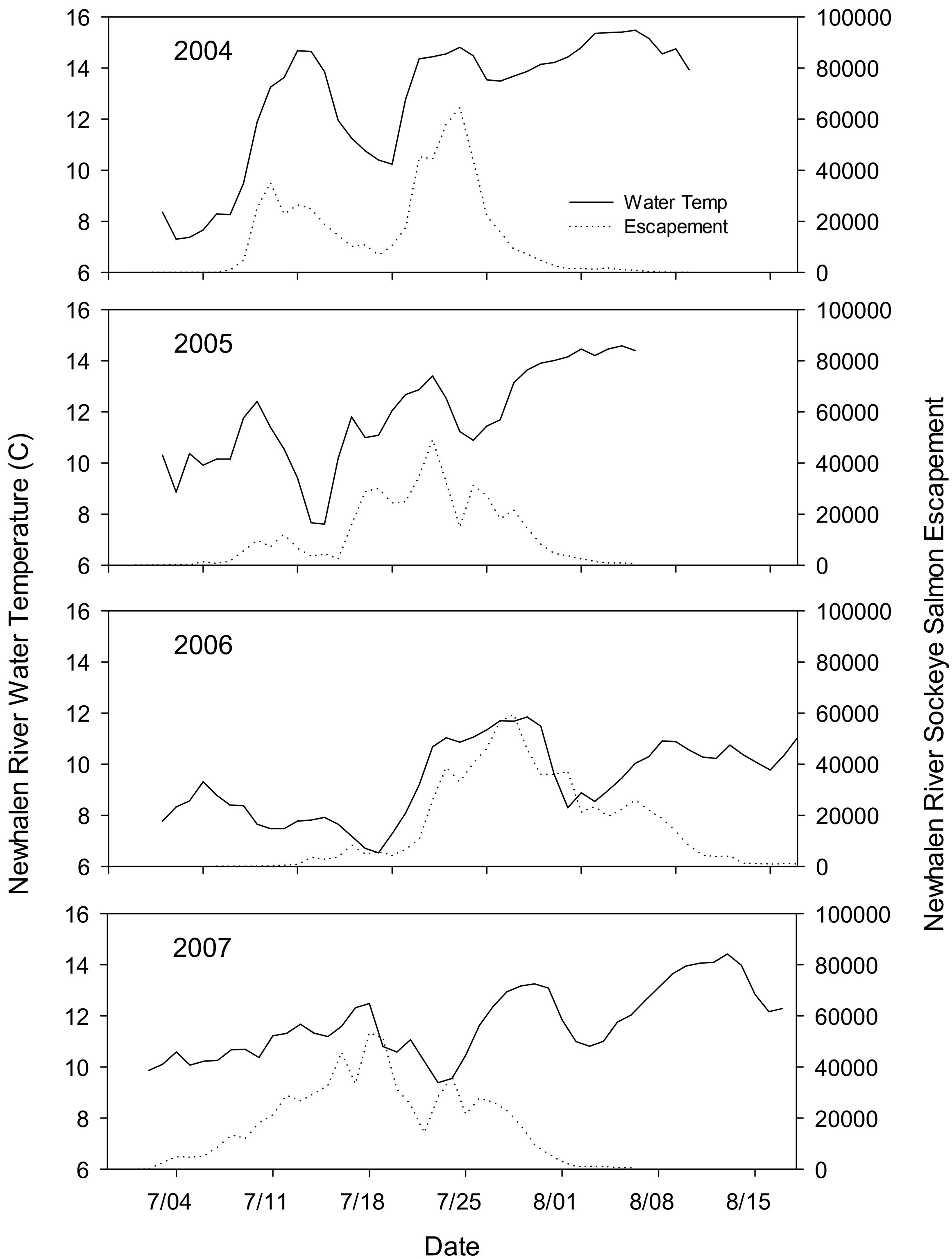

Figure 20. Daily average water temperature and sockeye salmon escapement recorded at the Newhalen River counting tower, 2004 – 2007.

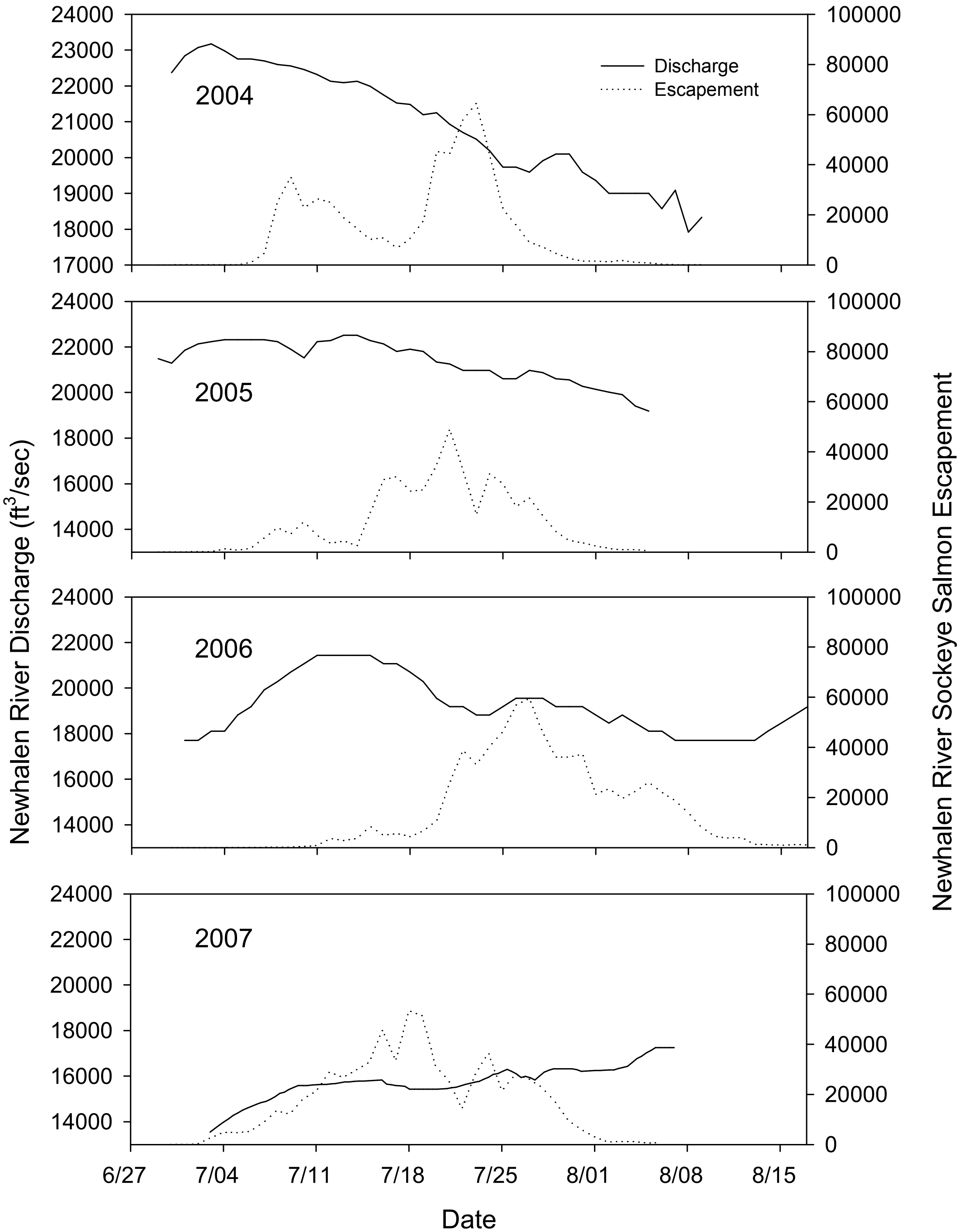

Figure 21. Estimated Newhalen River discharge (ft^3/sec) and sockeye salmon escapement recorded at the Newhalen River counting tower, 2004 – 2007.

Table 1. Summary of sockeye salmon escapement for Lake Clark and Kvichak River. Ninety-five percent confidence interval (CI) calculated as recommended by Reynolds et al. (2007). Kvichak River data from the Alaska Department of Fish and Game (2009).

Year	Lake Clark Escapement	95% CI	% of Kvichak	Kvichak River Escapement
2004	554,520	538,074 – 570,966	10	5,550,134
2005	445,620	429,560 – 461,656	19	2,320,422
2006	700,524	680,135 – 720,913	23	3,068,226
2007	667,572	652,329 – 682,815	24	2,810,208
Mean	592,059		19	3,437,225

Table 2. Age composition of salmon captured from Lake Clark spawning areas (LC), the Sixmile Lake subsistence fishery (Sub), and Tazimina River spawning area, 2004 – 2007. Sample sizes (n) and percentages (%) are shown.

		Age									
		1.2		1.3		2.2		2.3		All ages	
Year	Sample	n	%	n	%	n	%	n	%	n	%
2004	LC	531	59.5	124	13.9	209	23.4	29	3.2	893	100
	Sub	104	20.4	100	22.6	288	56.3	4	0.7	496	100
	Taz	20	20.4	2	2.0	76	77.6		0.0	98	100
2005	LC	220	22.1	636	64.0	40	4.0	98	9.9	994	100
	Sub	159	20.1	507	64.0	41	5.3	85	10.7	792	100
	Taz	21	21.0	48	48.0	5	5.0	26	26.0	100	100
2006	LC	334	41.8	411	51.4	19	2.4	36	4.5	800	100
	Sub	470	77.7	110	18.2	16	2.6	9	1.5	605	100
	Taz	85	86.7	13	13.3					98	100
2007	LC	490	54.4	335	37.2	25	2.8	50	5.6	900	100
	Sub	481	80.3	92	15.4	16	2.7	10	1.7	599	100
	Taz	92	92.0	8	8.0					100	100
All years	LC	1575	43.9	1506	42	293	8.2	213	5.9	3587	100
	Sub	1214	48.7	809	32.5	361	14.5	108	4.3	2492	100
	Both	2789	45.9	2315	38.1	654	10.8	321	5.3	6079	100

Table 3. Median mid-eye to fork (MEF) length (mm) of the female and male sockeye salmon sampled from Lake Clark spawning areas (LC) and the Sixmile Lake subsistence fishery (Sub) by age class. Sample size (n) per category is shown.

		Age																
		1.2				1.3				2.2				2.3				
		Female		Male		Female		Male		Female		Male		Female		Male		
Year		LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	LC	Sub	All
2004	MEF	517	524	530	536	583	588	593	598	522	530	540	550	587	590	611	583	536
	n	262	46	269	58	59	49	65	51	112	141	97	147	15	2	14	2	1389
2005	MEF	506	529	525	539	555	583	576	601	515	541	539	563	558	576	574	594	565
	n	113	86	107	73	317	297	319	210	21	29	19	12	46	51	52	34	1786
2006	MEF	501	514	519	529	552	573	563	587	518	522	537	527	551	568	567	605	530
	n	164	243	170	227	211	52	200	58	10	9	9	7	18	5	18	4	1405
2007	MEF	500	520	518	534	529	573	536	584	521	546	525	541	543	602	562	591	524
	n	248	223	242	258	158	34	177	58	12	7	13	9	19	1	31	9	1499
All	MEF	506	519	524	533	553	581	567	598	520	531	537	550	558	576	572	593	537
years	n	787	598	788	616	745	432	761	377	155	186	138	175	98	59	115	49	6079

APPENDIX

Appendix 1. Location and dates that Lake Clark and Tazimina River spawning areas and the Sixmile Lake subsistence fishery were sampled 2004 – 2007. Latitude and longitude coordinates are reported in decimal degrees and WGS 84 datum.

Water Body	Location	Latitude	Longitude	Dates
Lake Clark	Chi Point	60.075562	-154.604218	9/18 - 9/26
Lake Clark	Chulitna Lodge	60.280749	-154.264898	9/20 - 10/8
Lake Clark	Hatchet Point	60.374555	-153.914123	9/26 - 10/8
Kijik Lake	Kijik Lake	60.287034	-154.344779	9/23 - 10/17
Little Kijik River	Little Kijik River	60.307900	-154.293283	9/24 - 10/17
Little Lake Clark	Little Lake Clark	60.418352	-153.696577	9/30 - 10/26
Sixmile Lake	Sixmile Lake	59.943740	-154.866530	7/4 - 7/29
Sucker Bay Lake	Sucker Bay Lake	60.021547	-154.663638	9/1 - 9/14
Tazimina River	Tazimina River	59.931333	-154.813772	8/31 - 9/10
Tlikakila River	Tlikakila River	60.553744	-153.506704	10/7 - 10/23

Appendix 2. Lake Clark and Kvichak River sockeye salmon escapement, 1980 – 1984 and 2000 – 2007.

	Escapement		
Year	Lake Clark[a,b]	Kvichak River[c]	% of Kvichak
1980	1,502,898	22,505,268	7
1981	231,714	1,754,358	13
1982	147,294	1,134,840	13
1983	702,792	3,569,982	20
1984	3,091,620	10,490,670	29
2000	172,902	1,827,780	9
2001	222,414	1,095,348	20
2002	203,682	703,884	29
2003	264,690	1,686,804	16
2004	554,520	5,550,134	10
2005	445,620	2,320,422	19
2006	700,524	3,068,226	23
2007	667,572	2,810,208	24
1980 – 1984 Average	1,135,264	7,891,024	16
2000 – 2003 Average	215,922	1,328,454	19
2004 – 2007 Average	592,059	3,437,225	19
All years	685,249	4,501,372	18

[a] 1980 - 1984 data from Poe and Rogers (1984)
[b] 2000 - 2003 data from Woody (2004)
[c] Alaska Department of Fish and Game (2009)

Appendix 3. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2004. Kvichak River escapement data from the Alaska Department of Fish and Game, (2009).

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
6/20								
6/21								
6/22								
6/23	390	390	0.01	0.01				
6/24	714	1,104	0.01	0.02				
6/25	3,570	4,674	0.06	0.08				
6/26	19,290	23,964	0.35	0.44				
6/27	23,364	47,328	0.42	0.86				
6/28	4,992	52,320	0.09	0.95				
6/29	28,038	80,358	0.51	1.46	0	0	0.00	0.00
6/30	270,870	351,228	4.92	6.39	0	0	0.00	0.00
7/1	410,034	761,262	7.45	13.84	6	6	0.00	0.00
7/2	216,042	977,304	3.93	17.77	12	18	0.00	0.00
7/3	107,070	1,084,374	1.95	19.72	30	48	0.01	0.01
7/4	230,514	1,314,888	4.19	23.91	102	150	0.02	0.03
7/5	315,216	1,630,104	5.73	29.64	54	204	0.01	0.04
7/6	175,680	1,805,784	3.19	32.83	924	1,128	0.17	0.20
7/7	350,016	2,155,800	6.36	39.20	4,674	5,802	0.84	1.05
7/8	598,722	2,754,522	10.89	50.08	25,128	30,930	4.53	5.58
7/9	543,888	3,298,410	9.89	59.97	35,070	66,000	6.32	11.90
7/10	393,456	3,691,866	7.15	67.12	22,800	88,800	4.11	16.01
7/11	291,966	3,983,832	5.31	72.43	26,334	115,134	4.75	20.76
7/12	227,874	4,211,706	4.14	76.57	24,930	140,064	4.50	25.26
7/13	432,930	4,644,636	7.87	84.45	18,750	158,814	3.38	28.64
7/14	349,326	4,993,962	6.35	90.80	14,424	173,238	2.60	31.24
7/15	208,080	5,202,042	3.78	94.58	10,158	183,396	1.83	33.07
7/16	129,144	5,331,186	2.35	96.93	10,758	194,154	1.94	35.01
7/17	41,892	5,373,078	0.76	97.69	6,732	200,886	1.21	36.23
7/18	59,766	5,432,844	1.09	98.78	10,560	211,446	1.90	38.13
7/19	26,460	5,459,304	0.48	99.26	17,460	228,906	3.15	41.28
7/20	15,252	5,474,556	0.28	99.53	45,150	274,056	8.14	49.42
7/21	10,080	5,484,636	0.18	99.72	44,520	318,576	8.03	57.45
7/22	15,498	5,500,134	0.28	100.00	57,864	376,440	10.43	67.89
7/23					64,548	440,988	11.64	79.53
7/24					43,824	484,812	7.90	87.43
7/25					22,182	506,994	4.00	91.43
7/26					15,828	522,822	2.85	94.28
7/27					9,036	531,858	1.63	95.91
7/28					7,116	538,974	1.28	97.20

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Appendix 3. Continued.

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
7/29					4,542	543,516	0.82	98.02
7/30					2,634	546,150	0.48	98.49
7/31					1,470	547,620	0.27	98.76
8/1					1,560	549,180	0.28	99.04
8/2					1,230	550,410	0.22	99.26
8/3					1,728	552,138	0.31	99.57
8/4					1,020	553,158	0.18	99.75
8/5					780	553,938	0.14	99.90
8/6					300	554,238	0.05	99.95
8/7					132	554,370	0.02	99.97
8/8					48	554,418	0.01	99.98
8/9					102	554,520	0.02	100.00
Totals		5,500,134		100.00		554,520		100.00

Appendix 4. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2005. Kvichak River escapement from the Alaska Department of Fish and Game, (2009).

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
6/20	144	144	0.01	0.01				
6/21	126	270	0.01	0.01				
6/22	402	672	0.02	0.03				
6/23	426	1,098	0.02	0.05				
6/24	336	1,434	0.01	0.06				
6/25	420	1,854	0.02	0.08				
6/26	204	2,058	0.01	0.09				
6/27	1,938	3,996	0.08	0.17				
6/28	22,410	26,406	0.97	1.14				
6/29	4,242	30,648	0.18	1.32	0	0	0.00	0.00
6/30	32,310	62,958	1.39	2.71	72	72	0.02	0.02
7/1	131,670	194,628	5.67	8.39	18	90	0.00	0.02
7/2	191,190	385,818	8.24	16.63	132	222	0.03	0.05
7/3	206,346	592,164	8.89	25.52	144	366	0.03	0.08
7/4	172,584	764,748	7.44	32.96	1,284	1,650	0.29	0.37
7/5	123,630	888,378	5.33	38.29	672	2,322	0.15	0.52
7/6	98,496	986,874	4.24	42.53	1,608	3,930	0.36	0.88
7/7	165,186	1,152,060	7.12	49.65	5,616	9,546	1.26	2.14
7/8	234,966	1,387,026	10.13	59.78	9,594	19,140	2.15	4.30
7/9	189,984	1,577,010	8.19	67.96	7,218	26,358	1.62	5.92
7/10	130,872	1,707,882	5.64	73.61	12,162	38,520	2.73	8.65
7/11	177,822	1,885,704	7.66	81.27	6,588	45,108	1.48	10.13
7/12	150,690	2,036,394	6.49	87.76	3,462	48,570	0.78	10.90
7/13	100,140	2,136,534	4.32	92.08	4,356	52,926	0.98	11.88
7/14	51,498	2,188,032	2.22	94.30	2,502	55,428	0.56	12.44
7/15	24,750	2,212,782	1.07	95.36	15,684	71,112	3.52	15.96
7/16	24,558	2,237,340	1.06	96.42	28,806	99,918	6.47	22.43
7/17	17,760	2,255,100	0.77	97.19	30,042	129,960	6.74	29.17
7/18	21,006	2,276,106	0.91	98.09	24,264	154,224	5.45	34.62
7/19	15,120	2,291,226	0.65	98.75	24,864	179,088	5.58	40.20
7/20	17,808	2,309,034	0.77	99.51	34,710	213,798	7.79	47.99
7/21	9,096	2,318,130	0.39	99.91	49,050	262,848	11.01	59.00
7/22	2,292	2,320,422	0.10	100.00	32,646	295,494	7.33	66.33
7/23					14,892	310,386	3.34	69.67
7/24					31,296	341,682	7.03	76.70
7/25					27,186	368,868	6.10	82.80
7/26					18,156	387,024	4.08	86.88
7/27					21,588	408,612	4.85	91.72
7/28					14,448	423,060	3.24	94.97

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Appendix 4. Continued.

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
7/29					8,232	431,292	1.85	96.81
7/30					4,488	435,780	1.01	97.82
7/31					3,684	439,464	0.83	98.65
8/1					2,418	441,882	0.54	99.19
8/2					1,440	443,322	0.32	99.52
8/3					852	444,174	0.19	99.71
8/4					876	445,050	0.20	99.90
8/5					432	445,482	0.10	100.00
Totals		2,320,422		100.00		445,482		100.00

Appendix 5. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2006. Kvichak River escapement from the Alaska Department of Fish and Game (2009).

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
6/20	0	0	0.00	0.00				
6/21	12	12	0.00	0.00				
6/22	84	96	0.00	0.00				
6/23	126	222	0.00	0.01				
6/24	240	462	0.01	0.02				
6/25	276	738	0.01	0.02				
6/26	300	1,038	0.01	0.03				
6/27	294	1,332	0.01	0.04				
6/28	1,164	2,496	0.04	0.08				
6/29	7,080	9,576	0.23	0.31				
6/30	14,142	23,718	0.46	0.77	0	0	0.00	0.00
7/1	43,728	67,446	1.43	2.20	0	0	0.00	0.00
7/2	87,942	155,388	2.87	5.06	0	0	0.00	0.00
7/3	126,306	281,694	4.12	9.18	0	0	0.00	0.00
7/4	66,600	348,294	2.17	11.35	0	0	0.00	0.00
7/5	110,376	458,670	3.60	14.95	12	12	0.00	0.00
7/6	295,092	753,762	9.62	24.57	60	72	0.01	0.01
7/7	252,084	1,005,846	8.22	32.78	96	168	0.01	0.02
7/8	209,712	1,215,558	6.83	39.62	132	300	0.02	0.04
7/9	339,624	1,555,182	11.07	50.69	210	510	0.03	0.07
7/10	322,632	1,877,814	10.52	61.20	450	960	0.06	0.14
7/11	275,478	2,153,292	8.98	70.18	768	1,728	0.11	0.25
7/12	173,874	2,327,166	5.67	75.85	3,552	5,280	0.51	0.75
7/13	140,334	2,467,500	4.57	80.42	2,790	8,070	0.40	1.15
7/14	68,142	2,535,642	2.22	82.64	3,648	11,718	0.52	1.67
7/15	140,250	2,675,892	4.57	87.21	8,382	20,100	1.20	2.87
7/16	156,150	2,832,042	5.09	92.30	4,860	24,960	0.69	3.56
7/17	103,500	2,935,542	3.37	95.68	5,598	30,558	0.80	4.36
7/18	38,190	2,973,732	1.24	96.92	4,284	34,842	0.61	4.97
7/19	22,572	2,996,304	0.74	97.66	6,672	41,514	0.95	5.93
7/20	19,260	3,015,564	0.63	98.28	10,596	52,110	1.51	7.44
7/21	15,486	3,031,050	0.50	98.79	25,974	78,084	3.71	11.15
7/22	11,502	3,042,552	0.37	99.16	38,862	116,946	5.55	16.69
7/23	12,576	3,055,128	0.41	99.57	33,012	149,958	4.71	21.41
7/24	13,098	3,068,226	0.43	100.00	40,464	190,422	5.78	27.18
7/25					46,242	236,664	6.60	33.78
7/26					56,916	293,580	8.12	41.91
7/27					59,460	353,040	8.49	50.40
7/28					45,816	398,856	6.54	56.94

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Appendix 5. Continued

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
7/29					36,066	434,922	5.15	62.09
7/30					35,976	470,898	5.14	67.22
7/31					37,242	508,140	5.32	72.54
8/1					21,264	529,404	3.04	75.57
8/2					23,412	552,816	3.34	78.91
8/3					19,548	572,364	2.79	81.71
8/4					22,410	594,774	3.20	84.90
8/5					25,992	620,766	3.71	88.61
8/6					21,918	642,684	3.13	91.74
8/7					18,660	661,344	2.66	94.41
8/8					13,728	675,072	1.96	96.37
8/9					8,010	683,082	1.14	97.51
8/10					4,374	687,456	0.62	98.13
8/11					3,774	691,230	0.54	98.67
8/12					3,972	695,202	0.57	99.24
8/13					1,230	696,432	0.18	99.42
8/14					1,104	697,536	0.16	99.57
8/15					870	698,406	0.12	99.70
8/16					1,164	699,570	0.17	99.86
8/17					954	700,524	0.14	100.00
Totals		3,068,226		100.00		700,524		100.00

Appendix 6. Daily estimates of sockeye salmon escapement for the Kvichak and Newhalen Rivers, 2007. Kvichak River escapement from the Alaska Department of Fish and Game (2009).

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
6/20	0	0	0.00	0.00				
6/21	60	60	0.00	0.00				
6/22	144	204	0.01	0.01				
6/23	150	354	0.01	0.01				
6/24	312	666	0.01	0.02				
6/25	2730	3,396	0.12	0.12				
6/26	2430	5,826	0.10	0.21				
6/27	2400	8,226	0.10	0.29				
6/28	834	9,060	0.04	0.32				
6/29	1272	10,332	0.05	0.37				
6/30	42192	52,524	1.82	1.87	0	0	0.00	0.00
7/1	97446	149,970	4.20	5.34	6	6	0.00	0.00
7/2	130824	280,794	5.64	9.99	120	126	0.02	0.02
7/3	105774	386,568	4.56	13.76	2,538	2,664	0.38	0.40
7/4	102468	489,036	4.42	17.40	4,866	7,530	0.73	1.13
7/5	197742	686,778	8.52	24.44	4,722	12,252	0.71	1.84
7/6	302940	989,718	13.06	35.22	5,184	17,436	0.78	2.61
7/7	220026	1,209,744	9.48	43.05	8,688	26,124	1.30	3.91
7/8	253944	1,463,688	10.94	52.08	13,410	39,534	2.01	5.92
7/9	139596	1,603,284	6.02	57.05	12,150	51,684	1.82	7.74
7/10	220386	1,823,670	9.50	64.89	18,204	69,888	2.73	10.47
7/11	249066	2,072,736	10.73	73.76	21,288	91,176	3.19	13.66
7/12	155388	2,228,124	6.70	79.29	28,944	120,120	4.34	17.99
7/13	196422	2,424,546	8.47	86.28	26,736	146,856	4.00	22.00
7/14	123432	2,547,978	5.32	90.67	29,664	176,520	4.44	26.44
7/15	74844	2,622,822	3.23	93.33	32,730	209,250	4.90	31.34
7/16	38706	2,661,528	1.67	94.71	45,720	254,970	6.85	38.19
7/17	35592	2,697,120	1.53	95.98	33,450	288,420	5.01	43.20
7/18	42996	2,740,116	1.85	97.51	53,346	341,766	7.99	51.20
7/19	33006	2,773,122	1.42	98.68	51,306	393,072	7.69	58.88
7/20	15240	2,788,362	0.66	99.22	31,380	424,452	4.70	63.58
7/21	8472	2,796,834	0.37	99.52	25,380	449,832	3.80	67.38
7/22	11028	2,807,862	0.48	99.92	14,316	464,148	2.14	69.53
7/23	2346	2,810,208	0.10	100.00	28,332	492,480	4.24	73.77
7/24					36,486	528,966	5.47	79.24
7/25					21,504	550,470	3.22	82.46
7/26					27,816	578,286	4.17	86.63
7/27					26,208	604,494	3.93	90.55
7/28					22,896	627,390	3.43	93.98

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Appendix 6. Continued

	Kvichak River				Newhalen River			
			Percent of Total				Percent of Total	
Date	Daily Count	Cumulative Count	Daily	Cumulative	Daily Count	Cumulative Count	Daily	Cumulative
7/29					17,202	644,592	2.58	96.56
7/30					9,606	654,198	1.44	98.00
7/31					5,952	660,150	0.89	98.89
8/1					2,922	663,072	0.44	99.33
8/2					1,002	664,074	0.15	99.48
8/3					1,122	665,196	0.17	99.64
8/4					1,128	666,324	0.17	99.81
8/5					564	666,888	0.08	99.90
8/6					684	667,572	0.10	100.00
Totals		2,810,208		100.00		667,572		100.00

Appendix 7. Percent of fish counted at the Newhalen River counting towers by hour and bank, 2004 – 2007. Left Bank (LB) and Right Bank (RB) orientation are for observer looking downstream.

	2004		2005		2006		2007		All		
Hour	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB	Both
0	1.50	0.46	0.69	0.18	0.53	0.08	0.40	0.09	0.78	0.20	0.99
1	1.68	0.73	0.72	0.47	0.47	0.16	0.55	0.14	0.86	0.38	1.23
2	1.32	0.72	0.43	0.40	0.50	0.15	0.39	0.10	0.66	0.34	1.01
3	1.37	0.38	0.57	0.14	0.50	0.11	0.37	0.06	0.70	0.17	0.88
4	1.87	0.43	0.75	0.15	0.34	0.08	0.87	0.08	0.96	0.18	1.14
5	2.34	0.21	1.06	0.25	0.59	0.19	1.22	0.16	1.30	0.20	1.50
6	3.46	0.34	2.90	0.36	2.59	0.16	1.69	0.19	2.66	0.26	2.92
7	4.10	0.43	3.15	0.34	2.60	0.23	1.84	0.22	2.92	0.31	3.23
8	6.65	0.46	5.64	0.30	4.50	0.42	5.27	0.30	5.51	0.37	5.88
9	6.34	0.73	6.18	0.60	5.01	0.33	5.20	0.64	5.68	0.57	6.25
10	6.31	0.86	7.22	0.48	7.41	0.37	6.62	0.54	6.89	0.56	7.45
11	7.15	0.42	5.99	0.51	8.65	0.62	6.12	0.45	6.98	0.50	7.47
12	5.03	0.44	5.09	0.46	7.78	0.46	6.33	0.57	6.06	0.48	6.54
13	5.01	0.47	6.68	0.46	7.63	1.04	7.52	0.62	6.71	0.65	7.36
14	4.86	0.70	8.54	0.84	4.61	0.93	7.18	0.72	6.30	0.80	7.10
15	3.96	0.60	8.13	0.49	5.02	1.12	7.34	0.81	6.11	0.75	6.87
16	3.53	0.44	4.38	0.63	5.66	0.95	6.62	0.66	5.05	0.67	5.72
17	3.01	0.66	4.45	0.45	5.58	0.68	5.25	0.34	4.57	0.53	5.10
18	3.83	0.50	4.86	0.50	4.97	0.65	5.23	0.33	4.72	0.49	5.22
19	3.25	0.50	4.96	0.31	4.59	0.52	5.69	0.19	4.62	0.38	5.00
20	3.54	0.35	2.45	0.23	3.72	0.56	3.82	0.15	3.38	0.32	3.71
21	3.22	0.17	2.70	0.26	3.24	0.26	3.91	0.11	3.27	0.20	3.47
22	2.28	0.20	1.58	0.24	1.54	0.27	1.43	0.07	1.71	0.20	1.91
23	2.72	0.46	1.69	0.11	1.45	0.15	1.55	0.04	1.85	0.19	2.04
Total	88.34	11.66	90.82	9.18	89.50	10.50	92.41	7.59	90.27	9.73	100.00

Appendix 8. Daily average water temperature (C) and discharge (ft^3/sec) recorded at the Newhalen River counting tower, 2004 – 2007.

	Water Temperature				Discharge (ft^3/sec)			
Date	2004	2005	2006	2007	2004	2005	2006	2007
6/29						21,480		
6/30					22,370	21,290		
7/1	8.4	10.3	7.8		22,840	21,850	17,700	
7/2	7.3	8.9	8.3	9.9	23,070	22,130	17,700	
7/3	7.4	10.4	8.6	10.1	23,170	22,230	18,100	13,530
7/4	7.7	9.9	9.3	10.6	22,980	22,320	18,100	14,020
7/5	8.3	10.2	8.8	10.1	22,750	22,320	18,820	14,360
7/6	8.3	10.2	8.4	10.2	22,750	22,320	19,180	14,690
7/7	9.5	11.8	8.4	10.3	22,700	22,320	19,910	14,860
7/8	11.9	12.4	7.6	10.7	22,600	22,230	20,280	15,030
7/9	13.2	11.4	7.5	10.7	22,560	21,900	20,700	15,590
7/10	13.6	10.5	7.5	10.4	22,460	21,520	21,060	15,590
7/11	14.7	9.4	7.8	11.2	22,320	22,230	21,430	15,590
7/12	14.6	7.7	7.8	11.3	22,130	22,280	21,430	15,680
7/13	13.9	7.6	7.9	11.7	22,090	22,510	21,430	15,680
7/14	11.9	10.2	7.6	11.3	22,130	22,510	21,430	15,850
7/15	11.3	11.8	7.2	11.2	21,990	22,280	21,430	15,760
7/16	10.8	11.0	6.7	11.6	21,750	22,130	21,060	
7/17	10.4	11.1	6.5	12.3	21,520	21,810	21,060	
7/18	10.2	12.0	7.3	12.5	21,480	21,900	20,700	
7/19	12.8	12.7	8.1	10.8	21,200	21,810	20,280	15,420
7/20	14.4	12.9	9.2	10.6	21,250	21,340	19,550	15,420
7/21	14.4	13.4	10.7	11.1	20,930	21,250	19,180	15,420
7/22	14.5	12.5	11.0	10.2	20,700	20,970	19,180	15,590
7/23	14.8	11.2	10.9	9.4	20,510	20,970	18,820	15,760
7/24	14.5	10.9	11.1	9.6	20,190	20,970	18,820	15,850
7/25	13.5	11.4	11.3	10.5	19,730	20,600	19,180	16,330
7/26	13.5	11.7	11.7	11.6	19,730	20,600	19,550	16,370
7/27	13.7	13.1	11.7	12.4	19,590	20,970	19,550	15,590
7/28	13.9	13.6	11.8	12.9	19,910	20,880	19,550	16,060
7/29	14.1	13.9	11.5	13.2	20,100	20,600	19,180	16,590
7/30	14.2	14.0	9.6	13.3	20,100	20,560	19,180	16,190
7/31	14.4	14.1	8.3	13.1	19,590	20,280	19,180	
8/1	14.8	14.5	8.9	11.9	19,360	20,140	18,820	16,240
8/2	15.3	14.2	8.5	11.0	19,000	20,010	18,460	16,280
8/3	15.4	14.5	9.0	10.8	19,000	19,910	18,820	16,280
8/4	15.4	14.6	9.5	11.0	19,000	19,410	18,460	16,550
8/5	15.5	14.4	10.0	11.8	19,000	19,180	18,100	17,250
8/6	15.2		10.3	12.0	18,570		18,100	17,250
8/7	14.6		10.9	12.6	19,090		17,700	17,250
8/8	14.7		10.9	13.1	17,920		17,700	

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Appendix 8. Continued.

	Water Temperature				Discharge (ft^3/sec)			
Date	2004	2005	2006	2007	2004	2005	2006	2007
8/9	13.9		10.6	13.6		18,330	17,700	
8/10			10.3	14.0			17,700	
8/11			10.2	14.1			17,700	
8/12			10.7	14.1			17,700	
8/13			10.4	14.4			17,700	
8/14			10.1	14.0			18,100	
8/15			9.8	12.8			18,460	
8/16			10.3	12.2			18,820	
8/17			11.0	12.3			19,180	
Mean	12.8	11.8	9.4	11.7	20,938	21,369	19,207	15,748
Min	7.3	7.6	6.5	9.4	17,920	19,180	17,700	13,530
Max	15.5	14.6	11.8	14.4	23,170	22,510	21,430	17,250